# COMPARISON OF CLINICAL OUTCOME OF TITANIUM ELASTIC NAIL AND PLATE OSTEOSYNTHESIS IN PAEDIATRIC FEMORAL DIAPHYSEAL FRACTURES

**THE TAMILNADU DR. M.G.R.MEDICAL UNIVERSITY**
**CHENNAI, TAMILNADU**

**DISSERTATION SUBMITTED FOR**
**MS DEGREE (BRANCH II - ORTHOPAEDIC SURGERY)**

**APRIL 2016**

# CERTIFICATE

This is to certify that the dissertation entitled "COMPARISON OF CLINICAL OUTCOME OF TITANIUM ELASTIC NAIL AND PLATE OSTEOSYNTHESIS IN PAEDIATRIC FEMORAL DIAPHYSEAL FRACTURES" is a bonafide record of work done by Dr. SIVARAJ S in the Institute of Orthopaedics and Traumatology, Rajiv Gandhi Government General Hospital, Chennai, under the direct guidance of me.

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# DECLARATION

I, Dr.Sivaraj S, solemnly declare that the dissertation titled **"COMPARISON OF CLINICAL OUTCOME OF TITANIUM ELASTIC NAIL AND PLATE OSTEOSYNTHESIS IN PAEDIATRIC FEMORAL DIAPHYSEAL FRACTURES"** has been prepared by me under the able guidance and supervision of my guide Prof. N.Deen Muhammad Ismail, M.S.ORTHO., D.ORTHO., Professor & Director I/C, Institute of Orthopaedics and Traumatology, Madras Medical College, Chennai, in partial fulfilment of the regulation for the award of M.S.(ORTHOPAEDICS) degree examination of The Tamilnadu Dr. M.G.R. Medical University, Chennai to be held in April 2016.

This work has not formed the basis for the award of any other degree or diploma to me previously from any other university.

Signature of the Candidate

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# ACKNOWLEDGEMENT

I am deeply indebted to my beloved chief and my teacher, **Prof.N.Deen Muhammad Ismail, M.S.Ortho, D.Ortho., Professor of Orthopaedics and Director I/C,** Institute of Orthopaedics, Madras Medical College, Chennai for the able guidance, inspiration and encouragement he has rendered at every stage of this study.

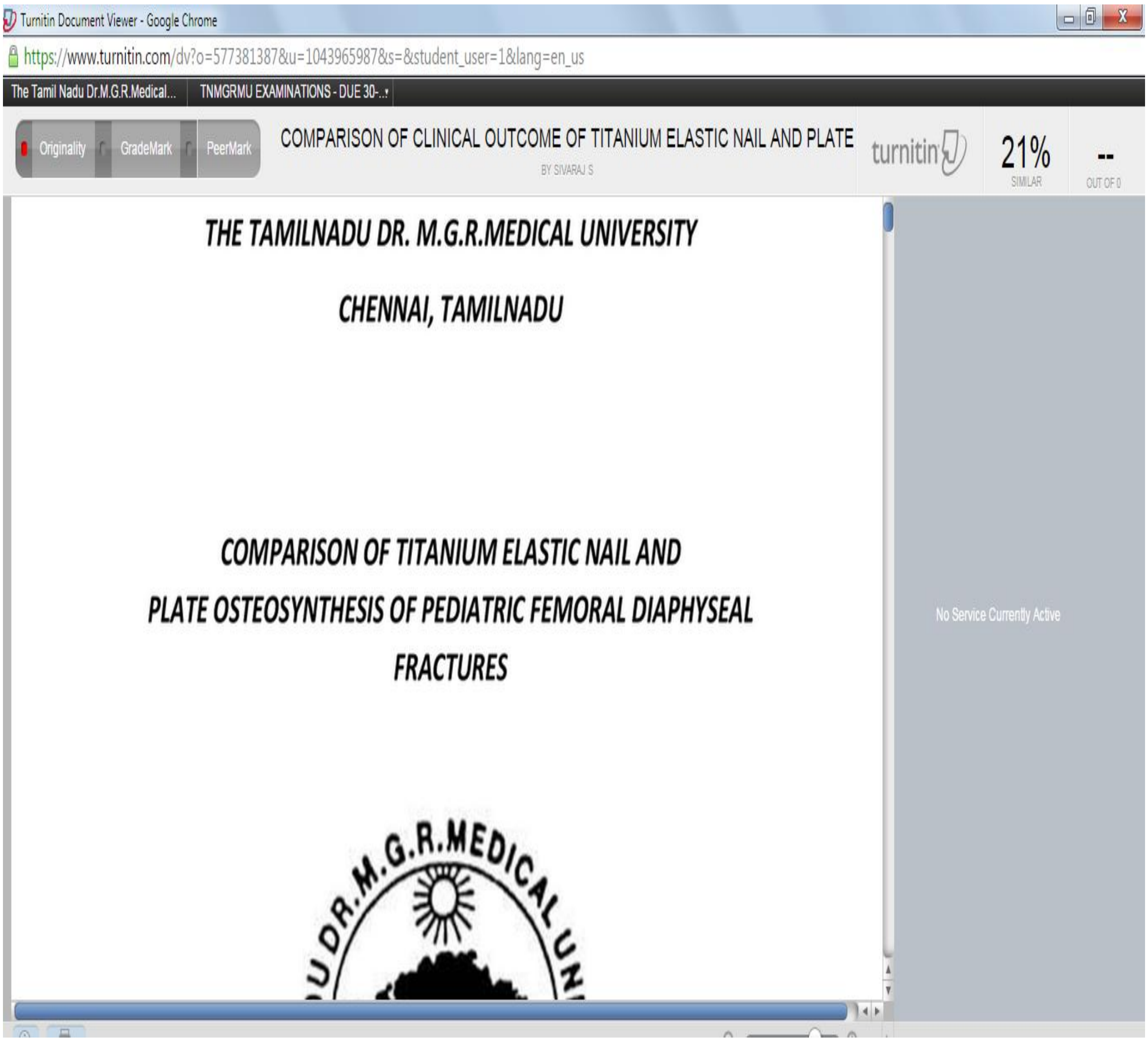
I am grateful to my beloved teachers **Prof.V.Singaravadivelu, Prof.A.Pandiaselvan, Prof.Nalli.R.Uvaraj, Prof.M.Sudheer, Prof.K.P.Manimaran, Prof.S.Karunakaran** for their invaluable help and guidance rendered to me in preparing this dissertation.

I express my heartfelt thanks to **Dr.S.Senthil Sailesh**, Assistant Professor, Institute of Orthopaedics, Madras Medical College for his excellent guidance and his valuable advice for preparing this study.

I express my heartfelt gratitude to **Dr.J.Pazhani, Dr.Nalli.R.Gopinath, Dr.G.Hementhakumar, Dr.M.Sameer** and other Assistant Professors of Orthopaedics, Madras Medical College, Chennai for their valuable advice and help in carrying out this study.

My sincere thanks **to The Dean, Madras Medical College**, Chennai for permitting me to utilize the clinical materials of the hospital.

I would like to thank my patients, friends, colleagues & family who have stood by me throughout this work and above all **the Almighty for His kindness throughout this study**.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# INTRODUCTION

Femoral shaft fractures account for 1.6% of all paediatric fractures. In children aged 5 years or younger, early closed reduction and application of spica cast is an ideal treatment for most diaphyseal fractures[1]. In skeletally mature adolescents, use of antegrade solid intramedullary rod has become the standard treatment. But, the best treatment for children between six to fourteen years of age is still under debate. Compared with younger children, patients in this intermediate age group have higher risk of shortening and malunion when conservative measures are used.

Children managed with traction and spica cast as a treatment modality has to undergo various adverse physical, social, psychological and financial consequences of prolonged immobilization. Other modalities such as external fixation, plates with screws & use of flexible intramedullary nail are available. However, the risk of certain complications, such as pin tract infection, refractures after external fixation and osteonecrosis of the neck with solid nails are there.

In recent times, fixation with flexible intramedullary nails has become a popular technique, for stabilizing femoral fracture in school going children. TENS fixation system is a simple, effective and minimally invasive technique. It gives stable fixation with rapid healing and prompt return of child to normal activity. This study was intended to analyse the results following the treatment of fracture shaft of femur by flexible intra medullary nail(TENS) and dynamic compression plating.

# AIM & OBJECTIVES

- To compare the clinical and radiological outcome of paediatric femoral diaphyseal fractures treated with titanium elastic nail and plate fixation in cases admitted in Institute of Orthopaedics And Traumatology, Rajiv Gandhi Government General Hospital over a period of 24 months from November 2013 to September 2015.

- This is a prospective and retrospective study, which will provide data and the possible variations in the clinical and radiological outcome of titanium elastic nail and plate osteosynthesis in paediatric femoral diaphyseal fractures, complications and benefits of both procedures.

# REVIEW OF LITERATURE

Paediatric femoral shaft fractures are dramatic, disabling injury to both patients and their family. But most of them unite without much complications. Not many years ago, traction and casting were the standard treatment for all femoral shaft fractures in children. During 18$^{th}$ century, French used the Hippocratic method of traction and[2] co-optation splinting in extension. The English were influenced by Sir Pott[3] who managed the patients on their side with Hip and Knee flexed. Starr and others[4] had difficulty in keeping the fragment aligned because of child's restlessness and the need to change the dressing.

The use of plaster became popular and was applied to femoral fractures initially in the form of splinting. In the year 1890, at John Hopkins hospital a full spica cast was first introduced for the first time. Fracture surgeons of 19$^{th}$ century applied the basic principles to treat the fractures. They recognized that these fractures healed well with conservative methods. In children, joint stiffness was not a problem unlike adults and delayed union was rare in children.

In the early $20^{th}$ century, fracture surgeons treated these fractures using lane plates, bone suturing with wires and external fixators which failed to show acceptable results. Nowadays, variable options are available such as external fixators, locking plates and flexible or locked intramedullary nailing are available. These newer techniques have helped to increase the convenience and decrease the cost.

Rush LV[5] (1968) studied about 211 cases of fracture shaft of femur in children. The objective of that study was to find an ideal method of treatment with good healing and minimal surgical trauma. He found out that any rod which is tightly impacted at the isthmus, might not give firm fixation of the lower fragment. Only curved rod driven deeply into the lateral condyles enhances fixation dynamically by 3 point pressure.

Gross RH et al[6] (1983) conducted a study on 72 patients aged 5-19 years who sustained femoral shaft fractures and were treated with immediate cast bracing at Oklahoma children's hospital. They observed that adolescent children shaft of femur fracture was difficult to manage conservatively which ideally requires closed intramedullary nailing. J.N. Ligier et al[7] (1988) studied 123 femoral shaft fractures in children aged from 5 to 16 years and found that TENS gave better results than conservative treatment. Reeves RB et al[8] (1990) performed comparative studies between groups of adolescents with a femur fracture treated by operative and conventional casting, traction techniques. The operative group had better results with a shorter hospitalization and reduced patient cost.

Heinreich et al[9] (1994) observed that the results obtained using flexible intramedullary nails for the stabilization of selected paediatric diaphyseal femur fractures are comparable to nonoperative treatment. It had less disruption to family life and shorter hospitalisation. Helphin RD et al (1994) compared the results of reamed intramedullary rods with flexible rods. He found that trochanteric growth arrest was more with reamed rods.

Canale TS et al[10] (1995) observed that open reduction and plate fixation of femoral fractures in the age group of 5 to 10 years will result in femoral overgrowth and limb length discrepancy. They observed that antegrade intramedullary insertion of a nail may cause growth arrest of trochanteric epiphysis and thinning of the bone of femoral neck, leading to coxa valga deformity in the future.

Mileski et al[11] (1995) observed that flexible IM nails hold many advantages over the reamed nails because the base of femoral neck and retinacular vessels were avoided during insertion of flexible nails. Gregory P et al[12] (1995) compared the use of ender with rigid antegrade nailing and found that both techniques produced satisfactory outcomes but flexible nails required much less operative and fluoroscopy time with similar patient satisfaction and outcomes. Carey TP and Galphin RD[13] (1996) reported that flexible nailing seemed better suited for peadiatric femoral fractures because most of them have a stable pattern.

Skak SU et al[14] (1996) compared the rigid IM nailing and flexible IM nailing in 52 femoral shaft fractures and found that the limb length discrepancies and valgus deformity the of hip is more in rigid IM nailing. Bar-on et al[15] (1997) compared the use of flexible Intramedullary nail with external fixator and reported that full weight bearing, full range of movements and early return to school, were earlier in patients who received flexible IM nails. Infante AF et al[16] (2000) reported that spica cast treatment in children was very user dependant and time consuming for the physician and caused economic loss for parents.

Cramer KE et al[17](2000) and Lee SS et al[18] (2001) in their studies, confirmed that flexible nails gave more advantages than the other techniques. Yameji et al[19] (2002) compared the callus formation after interlocking and flexible nailing. Callus appeared at a mean of 2-8 weeks in flexible nail and 3-9 weeks in interlocking group. The mean area of callus formation in the ender nailing and inter locking group were 699.4mm$^2$and 439.5mm$^2$respectively. This is because the elasticity of flexible nails promotes more callus formation.

Greisberg J et al[20](2002) and John Flynn et al in 2004 compared the patients treated with hip spica cast and flexible nails. They concluded that the patients treated with flexible nails had early ambulation, shorter hospital stay and early return to school. In multiple injured patients, compression plating is a safe and effective treatment in treating associated femur fractures.

Plating provides a biomechanically more stable construct than elastic intramedullary nailing. It remains a viable alternative in the treatment of length-unstable paediatric femur fracture patterns. Kregor et al[21] (1993) studied 15 femoral shaft fractures with multiple injuries or a head injury, that were managed with compression plating and concluded that plate fixation of the femur is a good treatment option for children who have femoral shaft fracture associated with major head injury or multiple injuries or both.

Caird MS et al[22] (2003) did a retrospective review of 60 children between age 3 to 15 years ( mean age 8 years) with femoral shaft fractures treated with open reduction and compression plate fixation and found 100% union rates and an overall ten percent complication rate. The authors concluded that the compression plate fixation has the advantage of rigid anatomic reduction, shorter hospital stay and early mobilization of the extremity. Disadvantages include scar over the thigh, need for hardware removal, increased blood loss and risk of re-fracture after hardware removal.

In 2003 Eron et al[23] did a retrospective review of 40 children (46 femur fractures), aged 4 to 10 years who were treated with open reduction and plate fixation. There were no non-unions. Complication included one case of osteomyelitis and one re-fracture. They observed an average of 1.2 cm (range 0.4-1.8 cm) limb length discrepancy.

Aksoy et al [24](2003) compared the results of compression plate fixation and flexible IM nailing in 36 femoral shaft fractures in children. They observed that flexible IM nailing gives shorter operating time, shorter healing time and a small incision which is cosmetically more acceptable. In 2005, Berger et al[25] treated 27 fractures of the femur with elastic intramedullary nailing. They concluded that TENS was an excellent treatment option for diaphyseal fractures in children with skeletal immaturity, especially for the femur.

In 2006, Caglar et al[26] compared the results of compression plating and flexible intramedullary nailing for paediatric femoral shaft fractures in 38 patients with 40 femoral shaft fractures. The average operating time was significantly shorter in the nailing group (P=0.039). A high union rate with shorter operating time was noted in the TENS group when compared to plate fixation.

Sink et al[27](2006) explained that most complications of open reduction and plating have been reported due to extensive surgical exposure and periosteal stripping. Twenty seven patients underwent sub-muscular bridge plating for unstable paediatric femoral fractures. Early callus formation was seen by six to eight weeks and stable bony union was achieved by 12 weeks in all patients. The authors concluded that sub-muscular plating is a reasonable option for operative stabilization of comminuted and unstable paediatric femoral fractures.

Saikia et al[28] (2008) studied twenty-two children with femoral diaphyseal fractures (20 closed, 2 open) who were stabilized with Titanium Elastic Nail (TENS) and concluded that TENS was an effective treatment of diaphyseal fractures of the femur in properly selected patients of the 6-16 years age group.

The Jacob et al[29] (2015) study included 45 children in the age group of 3-12 years who underwent TENS nailing for femur shaft fractures and found that the TENS nailing in the paediatric femur shaft fractures is a safe, easy and reliable surgery. It helps in early mobilisation of the patient and independent weight bearing at the earliest.

**ANATOMY OF FEMUR**

The femur or thigh bone is the longest and strongest bone in the body. Its shaft is almost cylindrical in most of its length and bowed with forward convexity. Its upper extremity has a rounded articular head, projecting medially on the short neck of the bone formed by the medial inclination of the upper part of the shaft. The distal or inferior extremity is more massive being in the form of double knuckle or condyle articulating with tibia. The upper end of the femur comprises a head, neck, greater and lesser trochanter. The head of the femur is more than a half sphere. It is directed upwards, medially and slightly forwards to articulate with acetabulum. It has an anteversion of 15°. The neck of femur which is about 5cm long, connects the head and shaft with which it forms an angle between 125° to 135°. The neck-shaft angle and anteversion present at birth was 150° and 40° respectively and decreases with age after proper weight bearing by the child. The anterior surface of the neck is flattened and at its junction with the shaft is marked by a prominent rough ridge termed as inter-trochanteric line.

The posterior surface of the neck at its junction with the shaft is termed as intertrochanteric crest. The greater trochanter is a large quadrangular portion at the upper part of the junction of the neck with shaft. It provides insertion for most of the muscles of gluteal region. The apex of the trochanter overlies trochanteric fossa. This fossa lies along the longitudinal axis of the shaft of femur. Many vascular foramina directed towards the head of the femur penetrate the upper and anterior surface of neck of femur. The lesser trochanter is a conical eminence which projects medially and backwards from the shaft at its junction with the lower and posterior part of neck. The shaft of femur is narrowest in its middle. It expands a little, as it is traced upwards. But it is wider near the lower end of femur.

## ANTERIOR BOWING

The most prominent feature of the femur is the anterior bowing. Wide individual variations exists in the magnitude of the bow. In its middle third, the shaft possess three surfaces and three borders. The anterior surface is smooth and gently convex in all direction. The lateral surface is directed more backwards than laterally. The posterior border is formed by a broad ridge, termed a linea aspera which usually forms a crest like projection with a distinct lateral and medial lip. In this situation, the compact bone of the shaft is increased in amount to withstand the compression forces concentrated here by its anterior curvature. The medial surface is directed medially and slightly backwards.

## MUSCULAR ATTACHMENT OF THE SHAFT

The shaft is thickly covered with muscles and cannot be felt through the skin. Its anterior and lateral surfaces provides attachment in their three fourth for the vastus intermedius. The lower portion of the anterior surface in covered by suprapatellar bursa. The lower portion of the lateral surface is covered by vastus lateralis, and the medial surface is covered by vastus medialis. In addition to the attachment already described, the linea aspera receives adductor longus, intermuscular septa and short head of biceps femoris.

**The Perforating arteries:** These cross the linea aspera from medial to lateral side under the tendinous arches in the Adductor Magnus and short head of biceps femoris. The foramina for nutrient arteries are situated close to the linea aspera.

## THE MEDULLARY CAVITY OF FEMUR

The shaft of femur is a cylinder of compact bone with a large medullary cavity. The wall of the cylinder is thick in the middle third of the shaft and becomes thinner above and below. Thus the narrowest region of the medullary canal is located immediately proximal to the middle. In the isthmus region the cortex has its greatest thickness. Proximally, the cavity becomes slightly larger towards the lesser trochanter. After that, it widens rapidly and is filled with dense network of trabeculae. Distal from the middle, the canal widens gradually towards the distal diaphysis.

## OSSIFICATION OF FEMUR

The lower limb buds appears during fourth week of gestation. During the following week, a condensation of mesenchyme develops as the precursor of the femoral shaft. During the 6$^{th}$ week, it undergoes chondrification to form the initial model of femur. During the $8^{th}$ week, ossification commences, the primary ossification center develops in the femoral shaft. The secondary ossification center develops in the distal femur during the last two month of gestation. The capital femoral epiphysis ossifies during the first 6 months of postnatal period.

The greater trochanter center appears between second and fifth year and the lesser trochanter center between ninth and thirteenth year. These centers fuse independently with the shaft immediately after puberty. The head fuses with the shaft at 14-16 years and lower end with the shaft between 16-18 years.

**BLOOD SUPPLY OF FEMUR**

In 1953 P.G.Laing[30] gave a detailed account of the blood supply of femoral shaft. His study revealed 4 main arterial system supplying femur, that are periosteal, diaphyseal, metaphyseal and epiphyseal. He stated that, nutrient arteries of the femur are 2 in number and enter the shaft at linea aspera. In children, the superior artery passes downwards, and the inferior passes upwards. His conclusion was that the size of arteries is related to the size of bones and it decreases with increasing age. He also showed the nutrient artery arise from one or the other perforating branch of Arteria

Profundus Femoris. First nutrient artery arises from inferior perforating branch. Major arteries do not enter the lower third of femur. A fracture at the upper third and middle third would deprive blood to the proximal fragment and at the junction of middle third and lower third, will deprive blood to the lower third.

In conclusion, he stated that, most of the medullary vessels were damaged by passing correctly fitting nail, causing least damage to the periosteum and linea aspera. Linea aspera should never be stripped of its muscular attachments. The blood supply of an immature femur is more abundant than that of an adult. This blood supply is derived from both periosteal and endosteal vessels. The endosteal vessels, provides rich blood supply that promotes growth and allows rapid healing of the fracture. Haemorrhage in children following femoral shaft fracture is usually limited and less serious than adults. Vascular injuries are uncommon because the vessels are flexible and resistant to perforation. Once damaged, the contractile properties of the vessel allow prompt control of local haemorrhage. Thus, the percentage of blood loss following a fracture in children is less than in adults. Blood replacement is seldom necessary. There are several significant differences between the surgical anatomy of the femur of children and that of an adult. These differences have clinical significance.

**BONE CHARACTER**

Because of inherent flexibility and reduced tensile strength of immature bone, a child's fracture differs from adults. Open femoral fractures are seldom seen in infants and younger children because the bone tends to bend before it breaks. Since the edges of fractured fragments are not so sharp, penetration of the soft tissue occurs less frequently. Because of the abundant blood supply, union is rapid and consistent. Thick periosteum aids in protecting the adjacent soft tissues and facilitates union.

**PAEDIATRIC FEMORAL SHAFT FRACTURES**

Femoral shaft fractures including sub-trochanteric and supra-condylar fractures, represent approximately 1.6% of all bony injuries in children. The male to female ratio is 2.6:1 with a bimodal distribution. The first peak is in early childhood and the second in mid adolescence.

**MECHANISM OF INJURY**

In Children, most of the fractures are due to fall from height. Most of the injuries in children are due to fall from swings in the play ground and these low energy accidents may cause femoral shaft fractures in a pathologic bone. In Blount's[31] classic text of fractures in children, he states that approximately 70% of paediatric femoral fractures are diaphyseal. Femoral shaft fractures are commonly isolated injuries or associated with minor trauma such as abrasion or contusion. High velocity trauma in children produces unstable fracture pattern, with a constellation of more severe and life threatening injuries. Child abuse causes a spectrum of injuries, including fractures of femoral shaft. In children younger than walking age, 80% of femoral fractures are caused by child abuse.

According to Green and Haggerty[32], an abused child has a 50% chance of father battering and 10% chance of death. Stress fractures of the femur have been described in skeletally immature patients, and they result from sports activities.

**MODE OF DISPLACEMENT**

In resting position, the femur is relatively neutral due to balanced muscle pull. In proximal shaft fracture, the proximal fragment assumes a position of flexion (illiopsoas), abduction (abductors), and lateral rotation (short external rotators). In mid-shaft fractures, the effect is less extreme as there is compensation by abductors and extensor attachments on the proximal fragment. Distal shaft fractures produce a little alteration in the proximal fragment position as most muscles are attached to the same fragment producing balance. Due to the pull of gastrocnemius, supra condylar fractures assume hyperextension position.

## DIAGNOSIS

Most patients with femoral shaft fractures are unable to walk and are in extreme pain. A physical examination is usually sufficient to document the presence of a femoral fracture. The child should be examined thoroughly. Hypotension rarely results from an isolated femoral fracture. Waddell's triad[33] of femoral fracture which includes intra-abdominal, intra-thoracic and head injury are usually associated with high velocity automobile accidents. Patients are checked for signs of hypovolemic shock and adequately resuscitated with intravenous fluids and blood.

## IMAGING

## X-RAY FINDINGS

X-ray evaluation of the entire femur including the hip and knee is needed, because injuries to the adjacent joints are common. The limb should be allowed to settle at its resting length and tube to plate distance should be at least the standard 1 meter. Ruling out the presence of additional injuries is also an essential feature of the initial examination. Inaccurate length measurements may occur for several reasons. If the tube – plate distance is too short(less than 80cm tube to plate distance), there will be excessive magnification. A more serious problem is the malpositioned study in which oblique x rays give wrong interpretation. This problem can be prevented by proper positioning such that the beam is projected at right angle to the shaft of femur. In many spiral, oblique and comminuted fractures the exact amount of overriding may be difficult to measure. In such situations, it may be necessary to take an x-ray of the opposite femur with the same tube to plate distance for comparison.

Radiographic studies are also necessary to assess alignment in three planes rotational, frontal, and transverse. Rotational malalignment of femur may be assessed in several ways. If the fracture is distal where the bone is elliptical rather than round, a disparity in the bone diameter indicates malrotation. A second method of assessment is to estimate the position of the lesser trochanter and the most practical method is to determine where the shape of the fractured ends match.

## CLASSIFICATION OF FEMORAL SHAFT FRACTURES

Fractures of the shaft of femur may be classified in variety of ways. Each fracture should be identified and described and each has clinical relevance.

## OPEN VERSUS CLOSED FRACTURES

Fortunately open fractures are rare in children, but any degree of skin penetration is highly significant. Open fractures should be classified on the basis of Gustilo and Anderson.

## LEVEL

Fractures of the shaft are usually described as occurring in the proximal, middle and distal third of the shaft. 70% occur in mid shaft. Subtrochanteric fractures are those occurring upto 7.5cms below the lesser trochanter. Supracondylar fractures are those that occur just above the origin of gastrocnemius.

## PATTERN

Most children fractures are transverse, oblique or spiral in direction and rarely comminuted.

## DISPLACEMENT

Femoral shaft fractures are also classified according to the displacement pattern. Shortening is quantified on non traction lateral radiograph. Angular and rotatory deformities reflect the action of unbalanced muscle forces across the fractured shaft. Angulations are described by using the apex of the deformity as a reference. Unusual fracture patterns, birth fracture, fractures associated with child abuse, pathological fractures, and multiple fractures are also taken into consideration.

## TREATMENT OF FEMORAL SHAFT FRACTURES IN CHILDREN

The Orthopaedic literature on paediatric femur consists primarily of uncontrolled retrospective clinical series focusing on treatment alternative. Humberger and Eyring[34] stated, "The simplest, safest, and the most effective method should be the treatment of choice".

Dameron and Thompson[35] outlined seven principles of paediatric femoral shaft fracture care.

1) The simplest form of satisfactory treatment is the best.
2) The initial treatment should be the permanent treatment whenever possible.
3) Perfect anatomical reduction is not essential for perfect function.
4) Restoration of alignment is more important than the position of fragments with respect to one another.
5) More potential growth equals more probable restoration of normal architecture because of remodelling.
6) Over treatment is usually worse than under treatment.

7) Injured limb should be kept in Thomas splint with skin traction before starting definitive therapy.

Most Authors recommend treatment based on patient's age.

***Treatment option for femoral shaft fractures in children and adolescents***

| Age | Treatment |
|---|---|
| Birth to 24 months | Pavlik harness(newborn to 6 month)<br>Immediate spica cast<br>Traction(Bryant's/Gallow's) → spica cast |
| 24 months to 5 years | Immediate spica cast<br>Traction → spica cast<br>External fixation (rare)<br>Flexible IM rod (rare) |
| 6-11 years | Traction spica cast<br>Flexible Intra Medullary Nailing<br>Compression Plate<br>External fixation |
| 12 years to maturity | Flexible Intra Medullary Nailing<br>Compression Plate<br>Solid Inter locking nail<br>External Fixation |

**I: In Infants: New born to 6 months of age**, femoral fractures are usually stable because the periosteum is thick.

- ❖ For stable proximal and mid shaft fractures, simple splinting or pavlik harness is all that is required.
- ❖ For unstable fractures in infancy ,a pavlik harness with a wrap around the thigh is beneficial.
- ❖ For fractures with excessive shortening (more than 1 to 2cm) or angulations increased $\geq 30°$, spica casting is required.

**II: In children, from 6 months to 6 years of age,** the treatment of choice is early spica casting for femoral fractures with less than 2 cm shortening.Femoral fractures with more than 2 cm shortening or marked instability or fractures that cannot be reduced and held with spica casting may require 3 to 10 days of skin or skeletal traction.

- ❖ Skeletal stabilization with external fixators is reserved for children with open or multiple trauma.
- ❖ Large children in whom it is very difficult to maintain reduction in cast may be benefited by flexible Intra Medullary Nail.

III: Treatment of femoral fractures in children 6 to 11 years of age is highly controversial.

- ❖ For a stable and minimally displaced fracture, immediate spica casting may be done.
- ❖ However, in large children with unstable comminuted fractures, traction followed by application of a cast or immediate spica cast may be necessary.
- ❖ Enthusiasm for treatment that decreases the hospital stay has led to use of external fixators and flexible intra medullary nails in children more than 6 years of age.
- ❖ Compression plates have been reintroduced as technique with low risks and significant benefit in the management of paediatric femoral fractures.
- ❖ In older children and adolescents, antegrade nailing has been recommended as a standard procedure, but the recognized risks of vascular trauma and growth disturbance has led to limited use of this as a standard technique.

***Acceptable angulations and shortening in paediatric femur fracture:***

| Age | Varus/Valgus Degree | Anterior/ Posterior Degree | Shortening (mm) |
|---|---|---|---|
| Birth to 2 years | 30 | 30 | 15 |
| 2-5 years | 15 | 20 | 20 |
| 6-10 years | 10 | 15 | 15 |
| 11 years to maturity | 5 | 10 | 10 |

***Advantages and Disadvantages of various treatment options***

| Fixation | Advantages | Disadvantages |
|---|---|---|
| Spica Casting | No scar, No operation | Uncomfortable, Skin problems and loss of reduction |
| Skeletal traction | No operation, closed treatment | Loss of reduction, long time immobilization, pin tract infection |
| External fixation | Percutaneous fixation, early mobilization | Pin tract infection, secondary fractures and refractures |
| Plate osteosynthesis | Immediate stability and mobilization | Large incision and scarring, hardware removal |
| Flexible IM nails | Small incision, early mobilization | Possibility of rotational instability, hardware removal is necessary |
| Locked intramedullary nailing | Immediate stability and mobilization | Risk of AVN, implant removal necessary |

***Indications for the surgical management of paediatric diaphyseal femur fractures***

- ❖ Children between the age of 3 to 9 years with failure to obtain or maintain an acceptable reduction.
- ❖ Children between the age of 3 to 9 years with multiple system injuries.
- ❖ Social: Children between the age of 6 to 9 year of age in whom there are psychological, educational or economic factors that makes non operative treatment unacceptable.
- ❖ All children older than 10 year of age.
- ❖ Children with pathological fractures.

**COMPLICATIONS OF FEMORAL SHAFT FRACTURES**

***1. Limb length discrepancy***

- ❖ The most common sequale after femoral shaft fracture in children
- ❖ The fractured fragments of the femur may be overriding initially and femur length may be short at union. Growth acceleration occurs to make up the difference but often the acceleration continues and overgrowth may occur.

- ❖ Age seems to be the most constant factor, but fractures in the proximal third, oblique and comminuted fractures have also been associated with growth acceleration.
- ❖ According to Staheli et al[36], shortening is more likely in patients over 10 years of age, over growth is more likely in patients with age 2-10 years. Average overgrowth is 0.9 cm.
- ❖ The surgeon should not accept more than 2cm of shortening.

***2. Angular deformity***

Some degree of angular deformity is frequent after femoral shaft fracture in children, but this usually remodel with growth. Wallact and Hoffman[37]concluded that Angular malunion of up to 25° in any plane will remodel. In children older than 9 years, remodelling should not be relied on to correct angular deformity.

***3. Rotational deformity***

Rotational deformity is usually expressed in terms of Femoral Anteversion Angle [FAA] on the fractured side compared with the normal side. A difference of more than 10° has been the criterion of significant deformity. The goal should be to reduce a rotational deformity to 10°, based on alignment of proximal and distal femur radiographically and correct positioning with cast.

***4. Delayed and Non Union***

Uncommon in children. Typical causes are either infection or stress shielding which is often caused by fracture management itself. Treatment is the same as that for an adult.

***5. Infection***

Pin tract infection occurs with use of skeletal traction and external fixation, but most are superficial infection that resolves with local wound care and antibiotic therapy.

***6. Neurovascular Injury***

Nerve and vascular injuries are uncommon with femoral fractures in children. An estimated 1.3% of femoral fractures in children are accompanied by vascular injury.

***7. Compartment syndrome***

Rare, but it has been reported after femoral fracture and treatment. Thigh fasciotomy is indicated when the pressure is >30mm/Hg.

***8. Avascular Necrosis of the femoral head***

Sometimes occur with hip spica cast, when hip is placed in wide abduction, also may occur in antegrade nail insertion through piriform fossa.

## TITANIUM ELASTIC NAIL SYSTEM

### A. IMPLANT DESIGN AND CHARACTERISTIC FEATURES

The technique of Titanium elastic Nailing, adopted from existing flexible rod systems, was first described by surgeons from Nancy clinic in France. Ligier et al [38] reported the results of the Nancy experience in fractures of femoral shaft in the year 1988. This TENS is based on the theoretical concept by Firicia.[39]

### TENS PRINCIPLE

Biomechanical principle of TENS is based on the symmetrical bracing action of two elastic nails inserted into the metaphysis, each of which bears against the inner bone at three points. This produces the following four properties: flexural stability, axial stability, translational stability and rotational stability

### BIOMECHANICS

Working from the concept of three point fixation, they were able to improve the stability significantly by using two pre-tensioned nails inserted from the opposite sides of the bone. Ligier, Metazieu and their colleagues were able to show that titanium nails allowed greater elasticity than steel. They also proved that titanium nails, which can be accurately contoured and properly inserted, could impart excellent axial and lateral stability to diaphyseal fractures in long bones. Rotational stability was also better than what had been previously experienced, although this still remains the weakest point of this technique. The flexible rod is initially bent or curved. An elastic nail retains its memory. During intramedullary insertion, which is typically retrograde in femur, the relatively straight medullary canal forces the curved rod to straighten within the bone. “This elastic deformation causes a bending moment within the long bone which will tend to angulate the fracture in the direction and plane of the concavity of the rod, as the rods also want to return to its initial status”. This moment is counteracted by a second rod of matched diameter and curve, which balances the first rod with an equal but opposite moment.

The two intramedullary rods acts complimentarily to stabilize the fracture. The biologic fixation is not stable but sufficiently stable against angular, translation and deforming forces and is associated with early and exuberant callus formation. Typically no external immobilization is needed. Titanium nails have been distinguished from other nails such as Ender, made of stainless steel, which are not sufficiently elastic.

Prerequisite for optimum fracture stability by elastic nails:

1) Nails should be prebent in such a way that the apex is located at the fracture site.

2) Diameter of the nail should be atleast 40% of the internal diameter of the medullary canal. To determine the size of titanium flexible rods to be used, measure the diaphyseal internal diameter on both the anteroposterior and lateral views, divide by 2, and subtract 0.5 mm.

3) Both nails should be of same diameter.

4) Both the nails should be bent to the same extent.

5) When inserted, the nails should have maximum cortical contact at the fracture site in opposite directions.

**INDICATION FOR TENS NAIL**

1) All shaft fracture in children older than 5 years.

2) Children younger than 5 years who are not suitable for closed reduction and early hip spica.

3) Children with fracture shaft of femur with multiple system injury, multiple fractures and some pathologic fractures.

4) Social indication: When conservative treatment alternatives are unacceptable to patient's parents.

The ideal fracture for this technique is a transverse or short oblique diaphyseal fracture with minimal comminution in a long bone.

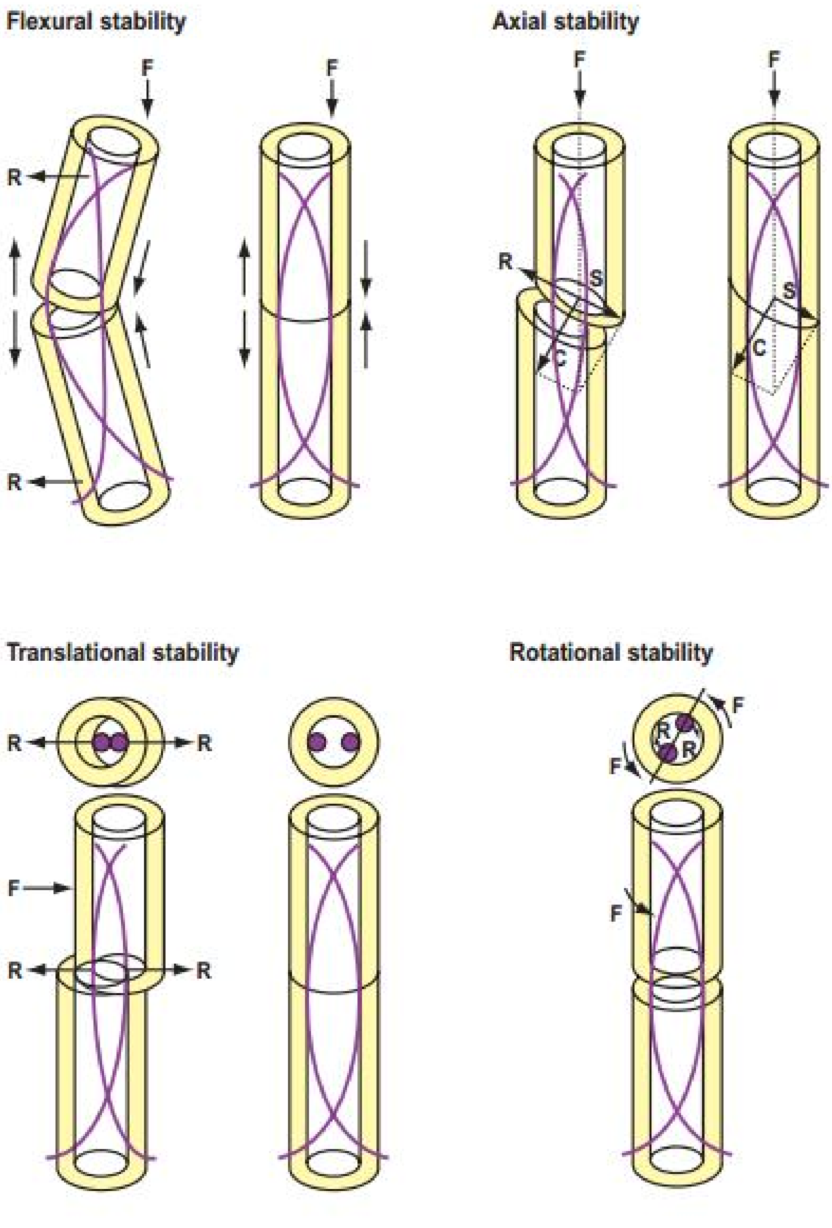
## CONTRAINDICATION

1) Intra articular fractures.

2) Complex femoral fractures, particularly in connection with over weight (50-60kg) or age (15-16 years).

3) Supracondylar fracture femur

# Biomechanical principle of TENS Nailing




**F** = force acting on the bone; **S** = shear force

**C** = compressive force; **R** = restoring force of the nail

## B. SURGICAL TECHNIQUE

### NAIL SELECTION

Titanium elastic nails are available in five diameters 2, 2.5, 3, 3.5 and 4 mm and are 440mm in length. The nails are colour coded for easy identification.

Nail diameter is equal to 0.4mm x narrowest internal minimum diameter of medullary cavity.

The following sizes are typically used for children of average stature.

6-8 years: 3.0mm nails

9-11 years: 3.5mm nails

12-14 years: 4.0mm nails

Always select two nails of the same diameter so the opposing bending forces are equal.

### PROCEDURE

### STEP I: POSITIONING OF THE PATIENT

Supine position in fracture table. If the fracture is fresh and without much overriding, it can be reduced by manual traction alone in a radiolucent table. Reduction checked by C Arm by AP and lateral views of the thigh from hip to knee. Patient should be lying in a way that is easily accessible by the surgeon from both sides. Surgical site preparation and draping of the thigh and hip is done.

**STEP II: CONTOURING THE NAIL**

Contour both nails into a bow shape with nail tip pointing towards the concave side of the bowed nail. The apex of the bend should be at the fracture site and at a distance, 3 times the diameter of bone. Usually it requires about 30° bend.

**STEP III: NAIL ENTRY POINT**

An incision is made on the lateral side of thigh, 2.5cm above the physis and extending distally for 2.5cm. The fascia lata is incised and vastus lateralis is retracted. Select the next largest drill bit relative to the diameter of nail. Drill sleeves can be used to protect the soft tissues. Penetrate the near cortex with the drill bit. With the drill bit rotating, but not advancing, slowly lower the drill to a 45° angle relative to the shaft axis. Now advance the drill bit at this angle until it reaches the medullary canal. Curved bone awl is used to enlarge the hole in 45° angulation. Medial entry point also can be made in a same manner.

**STEP IV: NAIL INSERTION AND FRACTURE REDUCTION**

Both the nails are inserted through entry points one after the other and are driven upto the fracture site. Using C-Arm, align the nail tip so that the convex side will glance off from far cortex. It is very important that sufficient reduction of the fragment is achieved so that about half of medullary canal overlap. ‘F’ tool can be used for reduction which is a radiolucent device. This nail is advanced 2cm into proximal fragment and then rotated. Motion of the proximal fragment demonstrates that the nail is in the proximal fragment. At this point, it is advanced further. By rotating this nail, further reduction of fracture can be accomplished, and then the second nail is inserted. It is advisable to cross the fracture site with both nails together. The first nail may cause displacement of the proximal fragment.

**STEP V: NAIL ADVANCEMENT AND CUTTING**

The traction is released and both the nails are advanced to their full length. Any deformity can be corrected by altering the position of the nail. By rotating the nails, we can correct Varus/Valgus angulations by C-Arm guidance. If there is any significant mal rotation, the child must be repositioned and nailing should be redone.

The cut off point for the nail should be 1 to 2 cm outside the cortex. Bending the nail tip sometimes irritates the soft tissues.

**STEP VI: THE CLOSURE**

The wound in closed in layers and dressing is applied. POP(Above knee Slab) may be applied for unstable cases.

**POST-OP PROTOCOL**

**Immediate Post OP:** Patients were received in post operative ward for observation. Limb elevation with pillow was given to all patients. Distal pulses and toe movements were checked for distal neurovascular deficit. Stretch pain also checked to rule out compartment syndrome. Patients encouraged to dorsiflex the ankle gently. If drain was kept, it also checked for loss of blood. If significant loss was detected it can be replaced by packed cells.

**Early Post Op:** Patient wound dressing changed on post operative day two. If wound is healthy then gentle knee exercises and quadriceps strengthening should be begun, but there should be no aggressive passive motion of the knee, which increases the motion at the fracture site and increases quadriceps spasm. Knee immobilizer either by POP or brace may be beneficial in decreasing knee pain and spasm[40].

**Late Post Op**: Sutures were removed on 11$^{th}$ post operative day and physical therapy continued

**Follow up:** Patients were asked to review on 4$^{th}$ week, 8$^{th}$ week, 12$^{th}$ week, 24$^{th}$ week, 1 year and radiographs and clinical assessment were done to assess the union. These radiographs were analysed for coronal and saggital plane malalignment and shortening across the fracture site. Patient's range of motion of knee, hip and limb length discrepancy, degree of pain or swelling documented. Rotational deformity of femur was measured using foot progression angle. All operative and post operative complications, secondary and unplanned procedures were noted.

**NAIL REMOVAL**

Usually nails for fracture shaft of femur are removed after 6 to 9 months.

## C. CAUSES OF FAILURES IN TENS TECHNIQUE

### *1. Biomechanical Principle failure*

. If 3 point fixation of TENS is not achieved, failure of reduction may occur.

### *2. Nail Diameter*

In general, nail diameter should be selected to corresponding to 40% of narrowest medullary space diameter. Differing nail thickness may lead to axial deformity.

### *3. Insertion point*

- ❖ Higher diaphyseal insertion can lead to severe muscle irritation.
- ❖ Too close to epiphysis may damage the growth plate.

### *4. Corkscrew Phenomenon*

Difficulties with fracture reduction as well as advancing the $2^{nd}$nail which makes the surgeon to rotate the nail more than 180°will lead to one nail being wind around the other. This process is called the ‘corkscrew phenomenon’. Then the nails will acts as single central nail and that will not be axially or rotationally stable.

### *5. Perforation of medial nail through calcar*

### *6. Failure to catch the fragment.*

## DYNAMIC COMPRESSION PLATING

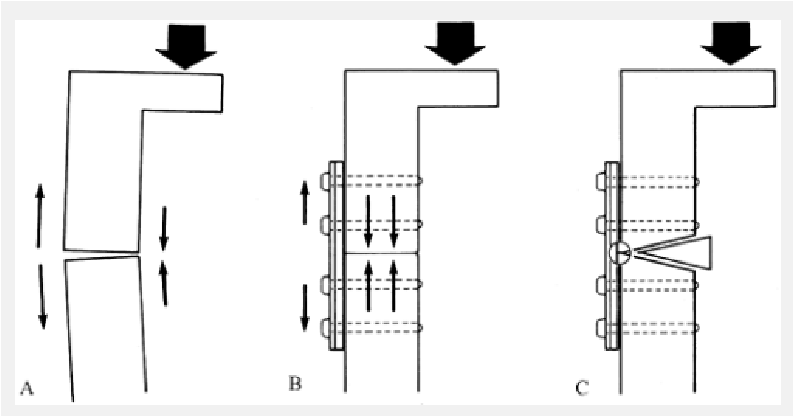
Open reduction and plate fixation provide anatomic reduction without the need for intraoperative fluoroscopy, easy to insert, applicable to all sizes of medullary canal and early mobilization. A long incision and consequent scar, possible increased blood loss and risk of infection are all reported as disadvantages.

All plates used in children in lower limb fractures also need to be removed once the fracture has united (usually between 9 to 12 months of post fixation) due to the risk of stress risers being created and the bone fracturing at the plate ends.

Disadvantages of plate fixation include long incision, stripping of periosteum, risks of plate breakage and stress fracture after plate removal. Plate fixation is recommended for children under 11 years of age with closed head injury or multiple trauma[41]. Plate fixation is an alternative treatment option in children older than 11 years who weigh more than 49 kg, and have a femoral canal that is too narrow for rigid trochanteric entry intramedullary nailing and flexible nailing. Traditional compression plating has demonstrated good results in children and adolescents. All the patients reported by Kregor et al[42] had multiple trauma, and this form of treatment was selected to stabilize the femoral fracture quickly and mobilize the patient.

## COMPRESSION PLATE PRINCIPLE

Pauwels explained principle of compression plate fixation and demonstrated its application in operative fracture treatment[43]. Every eccentrically loaded bone is subjected to bending stresses and deforms in a typical manner, with a gap on the convex side (tension side) and compression on the concave side of the bone. To restore the load-bearing capacity of an eccentrically loaded bone, the tensile forces on the convex side must be absorbed by a tension band (wire or plate). The bone itself must be able to withstand axial compression. This requires a medial buttress, usually supplied by the intact cortex. Thus, the implant absorbs the tension forces. Loading results in a dynamic increase of the axial interfragmental compression. In the absence of a medial buttress, which absorbs the compression forces, the plate is subjected to repeated bending stresses, which inevitably lead to fatigue failure and implant breakage.




A: Eccentric loading of the femur results in tensile forces on the lateral side and compression on the medial aspect of the bone

B: In the presence of a good bony buttress, the lateral plate acts as a tension band. The plate is therefore stressed only in tension, the bone in compression

C: In the absence of a bony buttress due to a cortical defect the plate undergoes cyclic bending, leading rapidly to fatigue breakage

**PREBENDING OF PLATE**

When a straight bone plate is applied to a straight bone surface under static compression, the near cortex is brought under compression, but the far cortex opens up. If a plate is bent sharply opposite to the fracture site before application, it first brings the far cortex under compression and then the near cortex.

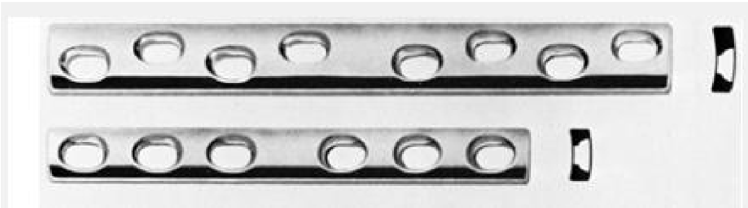
**BRIDGE PLATING**

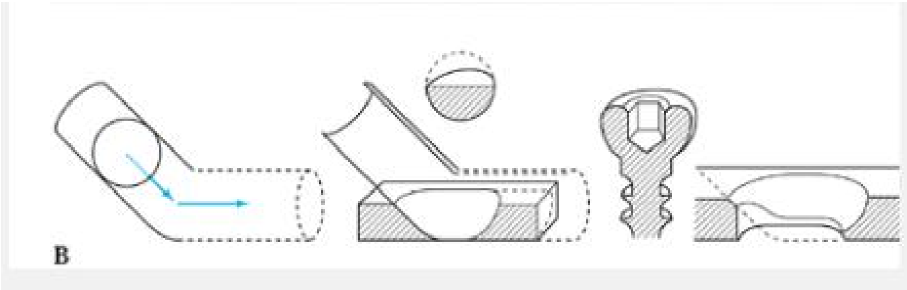
This newer method uses C-Arm assisted and percutaneous bridge plating through small incisions exposing the distal and proximal fragments, insertion of at least 2 screws in each fragment without much periosteal stripping, and disturbance to the fracture haematoma. This allows earlier and quicker bone healing.

Other advantages over compression plating include less pain, more rapid return to normal functioning, less scarring and better cosmetic results. Both Kanlic et al[44] and Sink et al[45]found favourable results in children with unstable femur fractures treated with submuscular bridge plating with complications occurring only in 6 out of 51 patients.

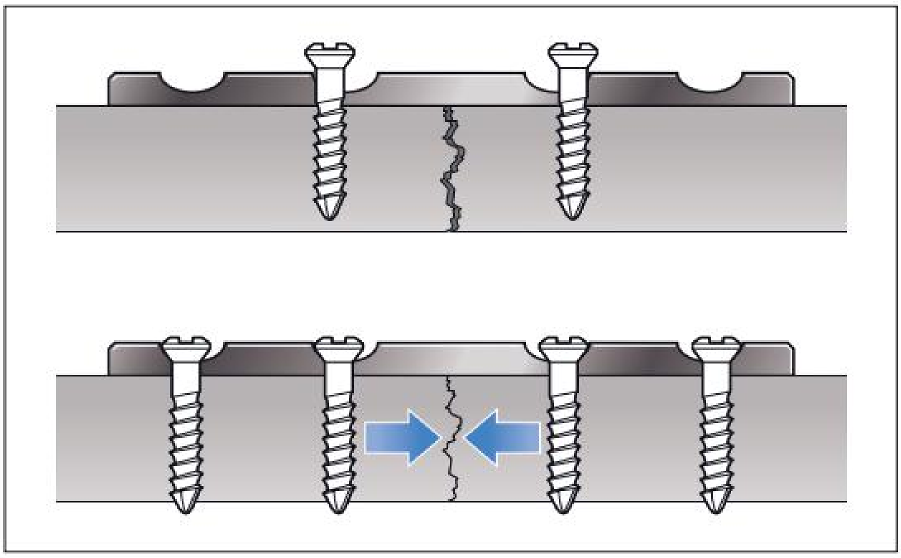
Broad DCP

Narrow DCP






Schematic representation of the spherical gliding principle of the DCP



Compression plating

## TECHNIQUE: STANDARD COMPRESSION PLATING

In a sterile operating room environment, after general anaesthesia had been given, the patient is placed on a radiolucent table and the entire extremity is prepared and draped. The femur is approached laterally. The vastus lateralis is retracted anteriorly to expose the femur. Soft tissue attachments to the bone are preserved as much as possible. Fragments are lagged into place and secured with a dynamic compression plate. A Narrow DCP or Broad DCP plate is used in children. Both interfragmentary compression and dynamic compression techniques can be used to achieve stability and anatomic alignment.

## POSTOPERATIVE PROTOCOL

External supports such as casts or cast braces are unnecessary after a properly performed plate application for a femoral fracture.

**Immediate Post OP:** Patients were received in post operative ward for observation. Limb elevation with pillow was given to all patients. Distal pulses and toe movements were checked for distal neurovascular deficit. Stretch pain also checked to rule out compartment syndrome. Patients encouraged to dorsiflex the ankle gently. If drain was kept, it also checked for loss of blood. If significant loss was detected it can be replaced by packed cells.

**Early Post OP:** Patient wound dressing changed on post operative day two. If wound is healthy then gentle knee exercises and quadriceps strengthening should be begun, but there should be no aggressive passive motion of the knee, which increases the motion at the fracture site and increases quadriceps spasm.

**Late Post Op**: Sutures were removed on $11^{th}$ post operative day and physical therapy continued.

**Follow up:** Each child was followed up to 1 year after the surgery. Patients were asked to review on $4^{th}$ week, $8^{th}$ week, $12^{th}$ week, $24^{th}$ week, 1 year and radiographs and clinical assessment were done to assess the union. After the appearance of calcified external callus, full weight bearing is allowed. These radiographs were analysed for coronal and saggital plane malalignment and shortening across the fracture site. Patient’s range of motion of knee, hip and limb length discrepancy, degree of pain or swelling documented. Rotational deformity of femur was measured using foot progression angle. All operative and post operative complications, secondary and unplanned procedures were noted.

# MATERIALS AND METHODS

This is a prospective and retrospective study in the patients admitted in Institute of Orthopaedics and Traumatology, Rajiv Gandhi Government General Hospital over a period of 24 months from November 2013 to September 2015 in whom fractures were treated by internal fixation either by standard dynamic compression plating or Titanium Elastic Nail System (TENS)

Post operatively, the patients were followed up for clinical and radiological outcome of internal fixation either by Dynamic Compression Plating or Titanium elastic nailing.

**INCLUSION CRITERIA**

Children and adolescent patient of age groups from 6 – 14 years with closed diaphyseal femur fracture

**EXCLUSION CRITERIA**

- ❖ Age less than 6 and more than 14 years
- ❖ Compound fractures
- ❖ Pathological fractures.

# OBSERVATION AND RESULTS

All patients were followed until fracture union occurred. The follow up period ranged from 6 months to 24 months. Results were analysed both clinically and radiologically.

***Age incidence***

| | **TENS** | **Plating** |
|---|---|---|
| 5-8 years | 3 | 5 |
| 8-12 years | 5 | 3 |
| 12-15 years | 2 | 2 |

Most Of patients (40%) are between 5- 8 years

***Sex incidence***

Male sex predominating with 55% femur fractures

| | **Male** | **Female** |
|---|---|---|
| TENS Nail | 5 | 5 |
| Plating | 7 | 3 |

***Mode of injury***

Fall from height is a more common mode of injury (45%) in our study

| | TENS | Plating |
|---|---|---|
| RTA | 3 | 6 |
| Fall from height | 6 | 3 |
| Fall of Heavy object | 1 | 1 |

***Side affected***

Right side (55%) was affected more commonly in our study

| | TENS | Plating |
|---|---|---|
| Male | 3 Right+2 Left | 6 Right + 1 Left |
| Female | 2 Bilateral + 1 Right + 2 Left | 1 Right + 2 Left |

***Pattern of fracture***

Transverse fractures (80%) are most common pattern in our study.

| | TENS | Plating |
|---|---|---|
| Transverse | 8 | 8 |
| Spiral | 0 | 0 |
| Oblique | 2 | 2 |

*Level of fracture*

In our study, Middle 1/3rd fractures (45%) were more common

| | TENS | Plating |
|---|---|---|
| Prox1/3rd Mid 1/3rd junction | 2 | 4 |
| Mid1/3rd | 4 | 5 |
| Mid 1/3rd distal 1/3rd junction | 4 | 1 |

**ASSOCIATED INJURIES**

- Head injury – 2
- Distal radius # – 1
- Supra condylar # Humerus – 1
- Lateral condyle # femur – 1

*Type of reduction closed/Open in TENS*

| Reduction | TENS |
|---|---|
| Closed | 8 |
| Open | 2 |

***Mode of Immobilization***

| | **TENS** | **Plating** |
|---|---|---|
| Above Knee slab | 3 | 1 |
| No immobilization | 7 | 9 |

***Stay in Hospital***

| | **TENS** | **Plating** |
|---|---|---|
| Avg stay | 11 days | 18 days |

***Time for Clinical Union***

| | **TENS** | **Plating** |
|---|---|---|
| Mean Time Of Union | 9.28 weeks | 13.87 weeks |

Time of clinical union was defined as the period between operation and full weight bearing without external support along with radiographically healed fracture (cortical continuity in all 4 cortices).

***TENS – Complication***

| | |
|---|---|
| Limb lengthening | 2(20%) |
| Infection | 0 |
| Delayed union / Non Union | nil |
| Nail Protrusion | nil |
| Mal alignment/ Varus angulation | 2(20%) |

***Plate – Complication***

| | |
|---|---|
| Infection | 2(20%) |
| Limb length discrepancy | 1(10% ) |
| Implant loosening | Nil |
| Non union | Nil |
| Mal Union | Nil |

**RANGE OF MOTION OF HIP AND KNEE**

One patient in TENS Group with bilateral femoral fracture had a stiffness of both knees which needed mobilization under anaesthesia. One patient in plating group with poly trauma had knee stiffness. Other patients had full range of motion of hip and knee, 1 patient had a local irritation which mandated TENS nail removal at $4^{th}$ month.

**LIMB LENGTH DISCREPANCY**

Two patients had 2cm limb length discrepancy in TENS group. One patient belonging to the plating group also had limb length discrepancy of 2cm.

**INFECTION**

Deep infection was seen in 2 patients in Plating group and it was controlled by antibiotics and wound debridement.

**DELAYED UNION AND NON UNION**

No cases of delayed or non union were seen in our series.

**MALALIGNMENT**

Two cases of varus malalignment (10° and 12°) were observed in TENS group. No cases of valgus, anteroposterior or rotational malalignment were observed.

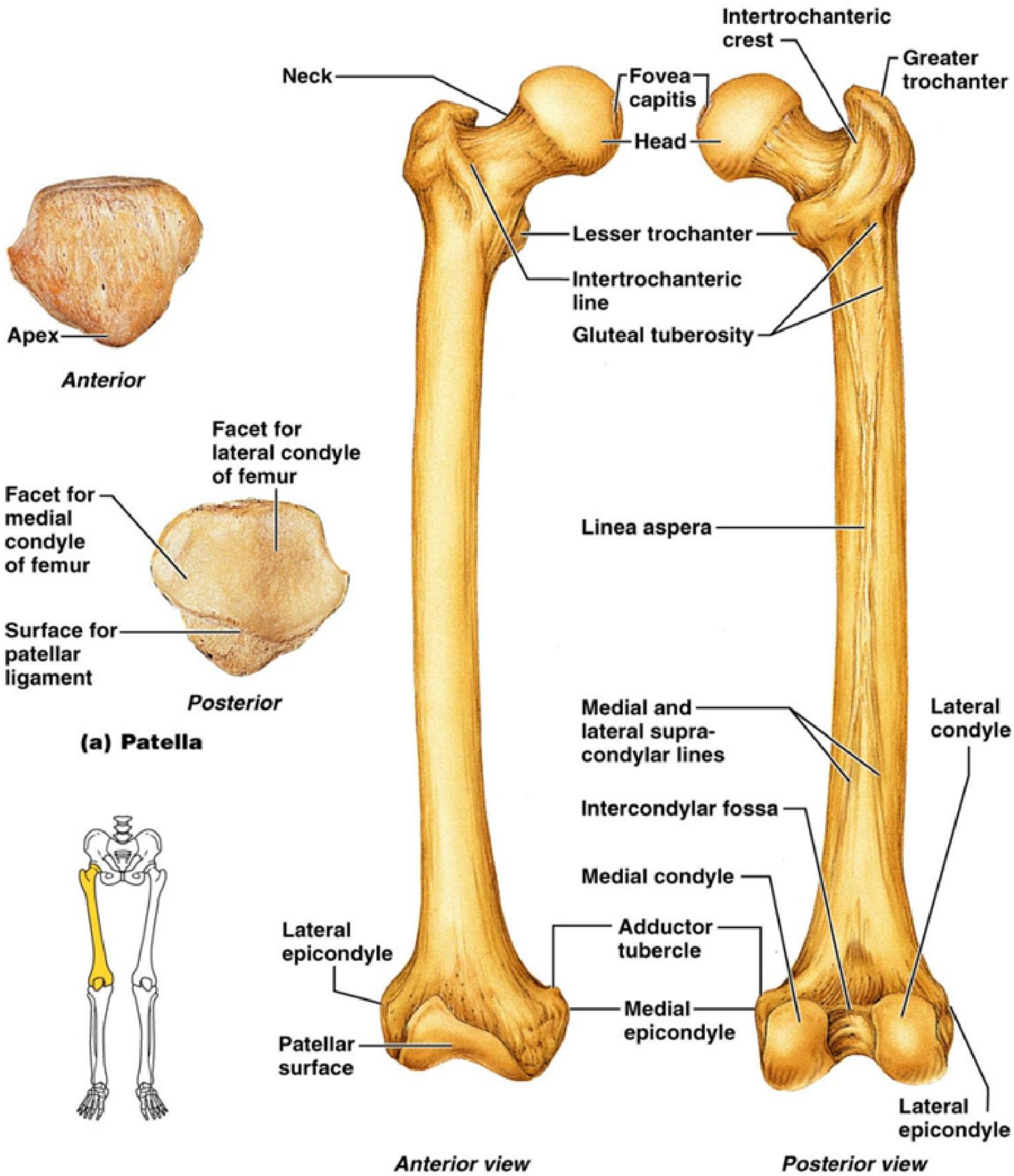
We analysed our final results with **TENS Evaluation Score given by Flynn et al[46].**

***Table: I: The Scoring Criteria for TENS***

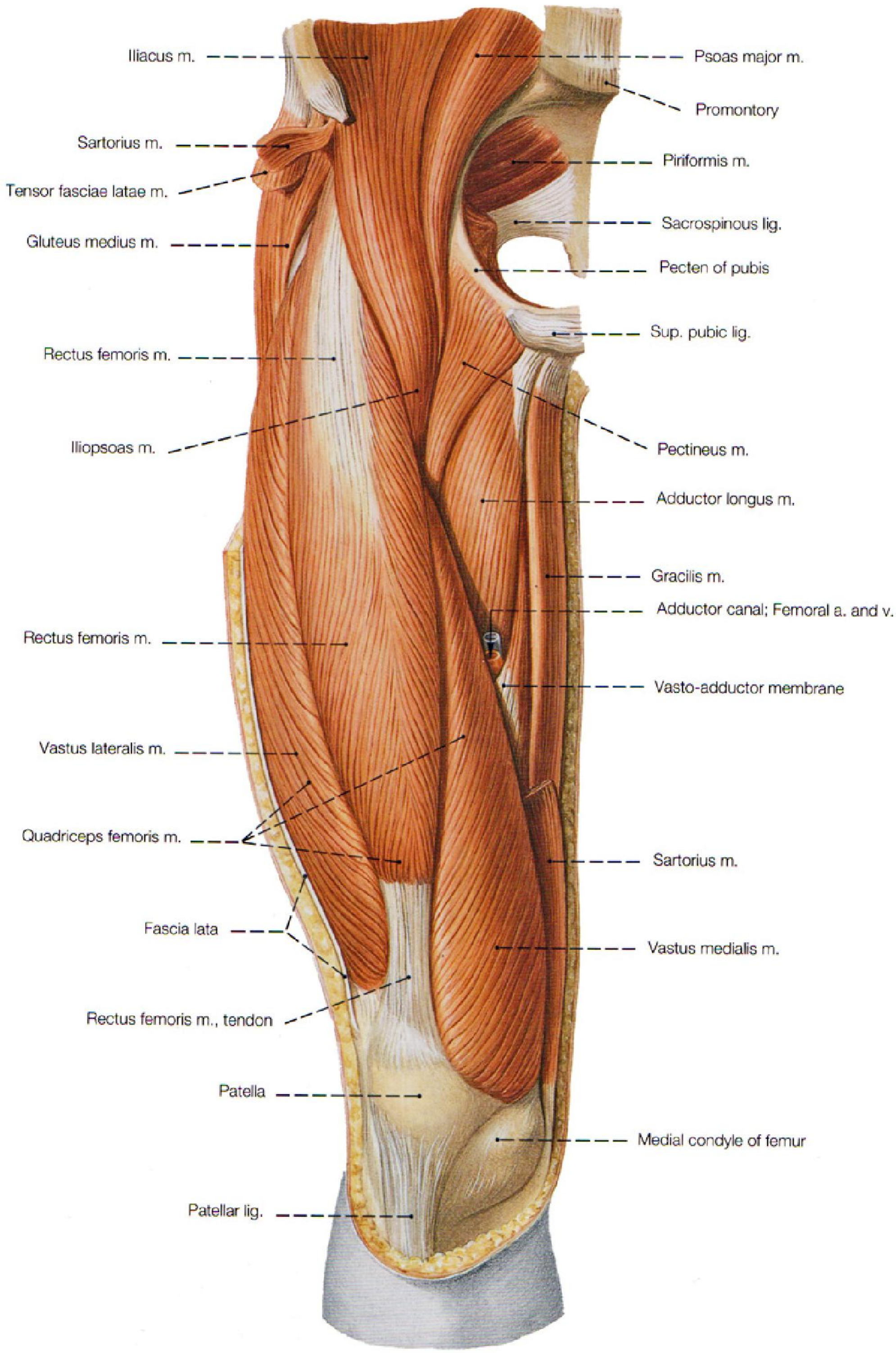
| | **Excellent** | **Successful** | **Poor** |
|---|---|---|---|
| **Limb length discrepancy** | **<1cm** | **<2cm** | **>2cm** |
| **Angulation/Mal alignment** | **5 °** | **10 °** | **>10 °** |
| **Pain** | **Absent** | **Absent** | **Present** |
| **Complication** | **Absent** | **Mild** | **Major complication or increased morbidity** |

| | **Results in DCP** | **Results in TENS** |
|---|---|---|
| Excellent | 8 | 8 |
| Successful | 0 | 1 |
| Poor | 2 | 1 |

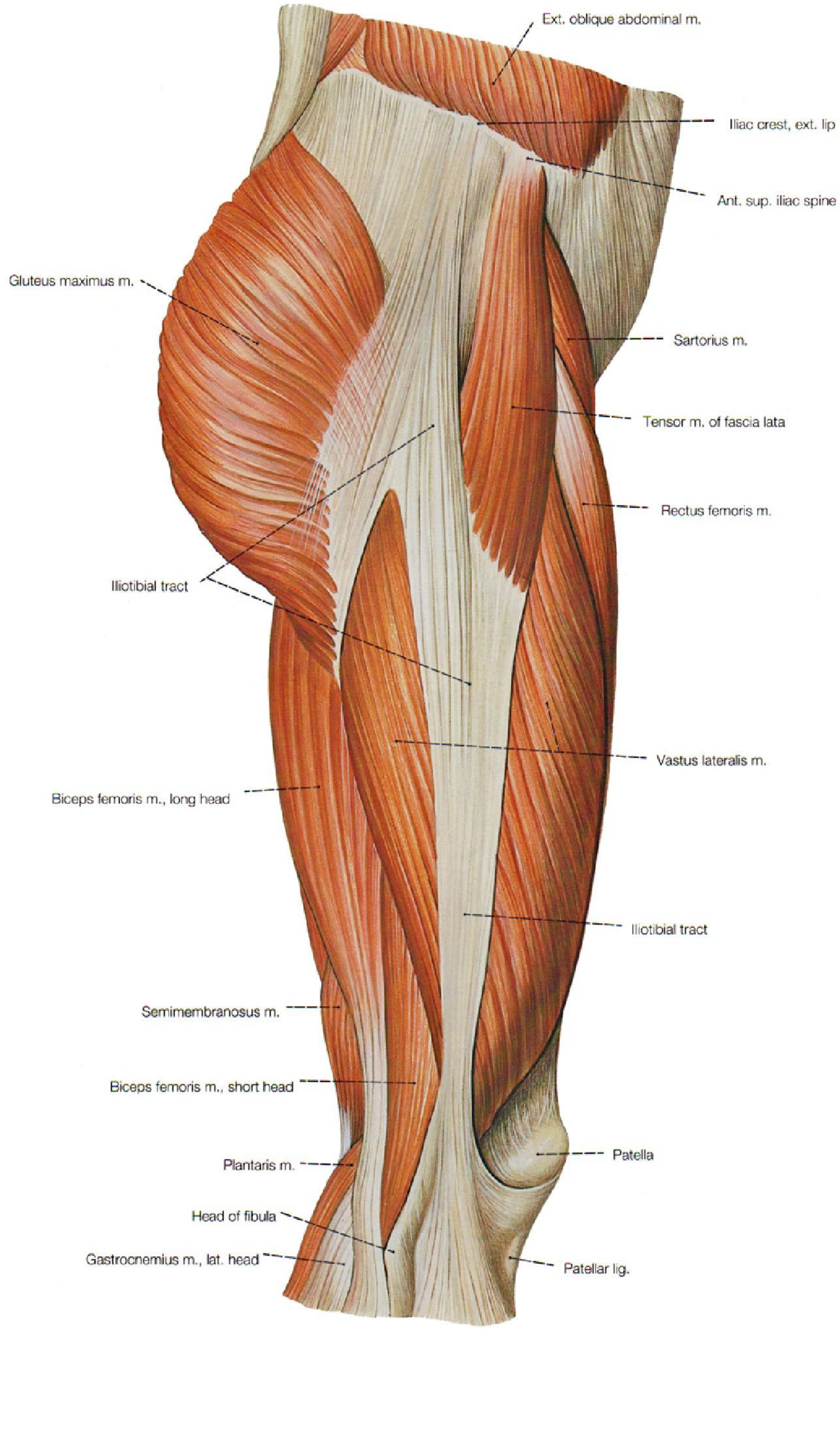
# FEMUR


Apex
Anterior
Facet for lateral condyle of femur
Facet for medial condyle of femur
Surface for patellar ligament
Posterior
(a) Patella
Neck
Fovea capitis
Head
Intertrochanteric crest
Greater trochanter
Lesser trochanter
Intertrochanteric line
Gluteal tuberosity
Linea aspera
Medial and lateral supra-condylar lines
Lateral condyle
Intercondylar fossa
Medial condyle
Lateral epicondyle
Adductor tubercle
Medial epicondyle
Patellar surface
Lateral epicondyle
Anterior view
Posterior view

# ANTERIOR THIGH MUSCLES

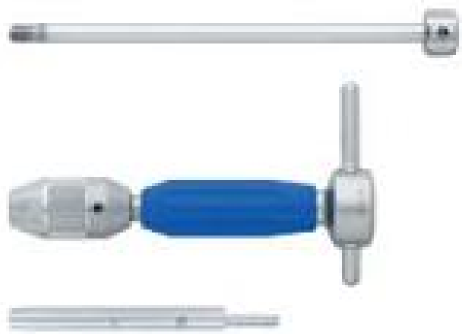


# LATERAL THIGH MUSCLES



## TENS INSTRUMENTATION

Awl for entry



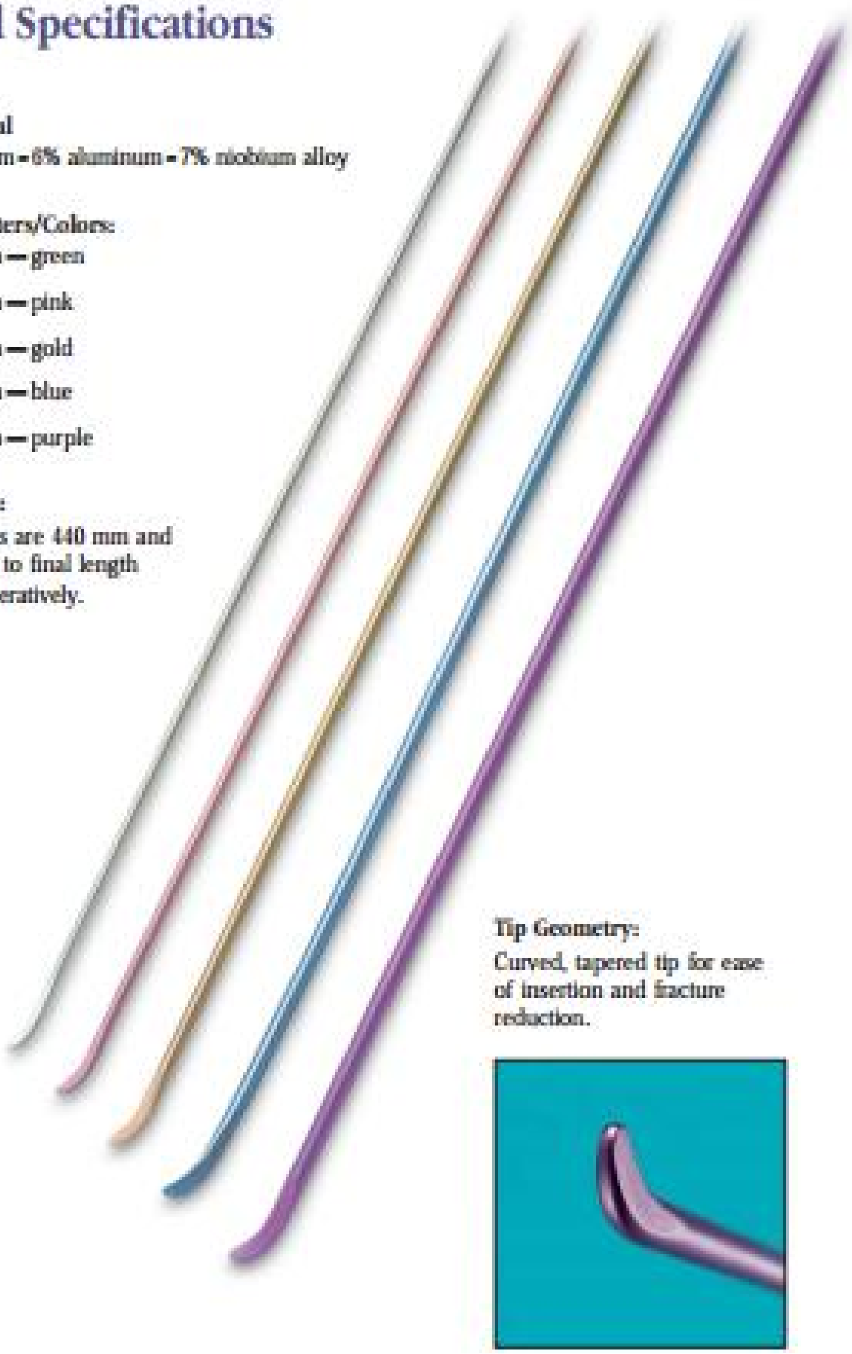
Inserter for TEN

Extraction pliers for TEN

Cutter for TEN

TENS instrument box

# Nail Specifications



**Material**
Titanium – 6% aluminum – 7% niobium alloy

**Diameters/Colors:**

2.0 mm — green

2.5 mm — pink

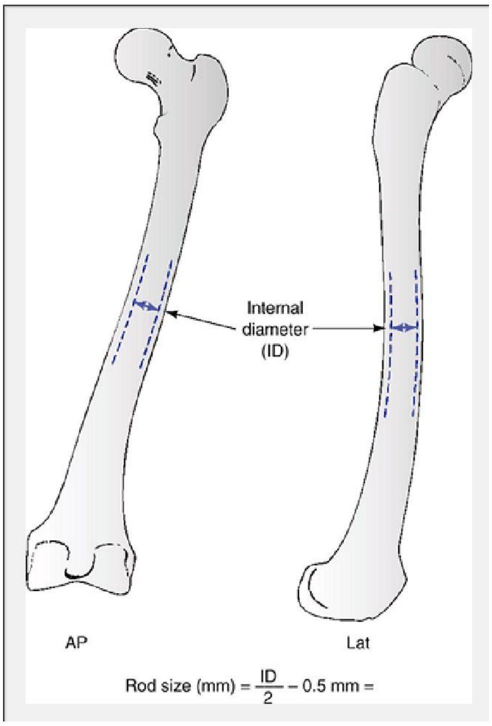
3.0 mm — gold

3.5 mm — blue

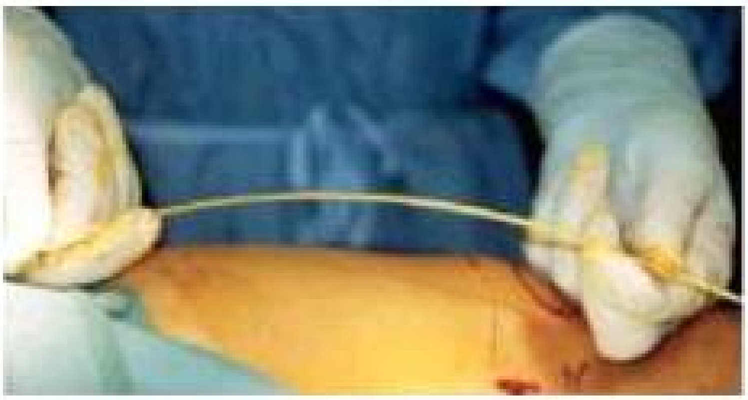
4.0 mm — purple

**Length:**
All nails are 440 mm and are cut to final length intraoperatively.

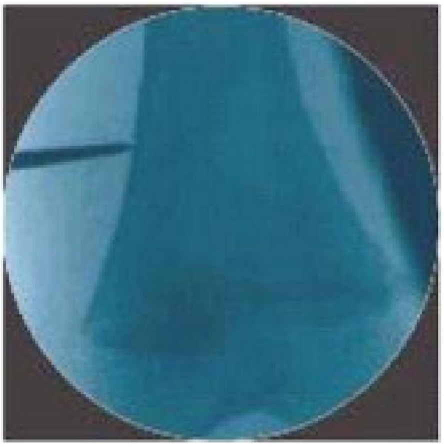
**Tip Geometry:**
Curved, tapered tip for ease of insertion and fracture reduction.

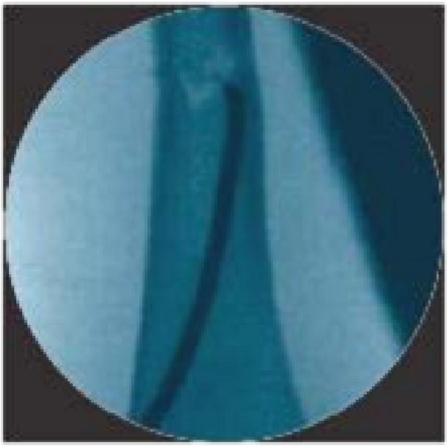



## PRE BENDING OF THE NAIL

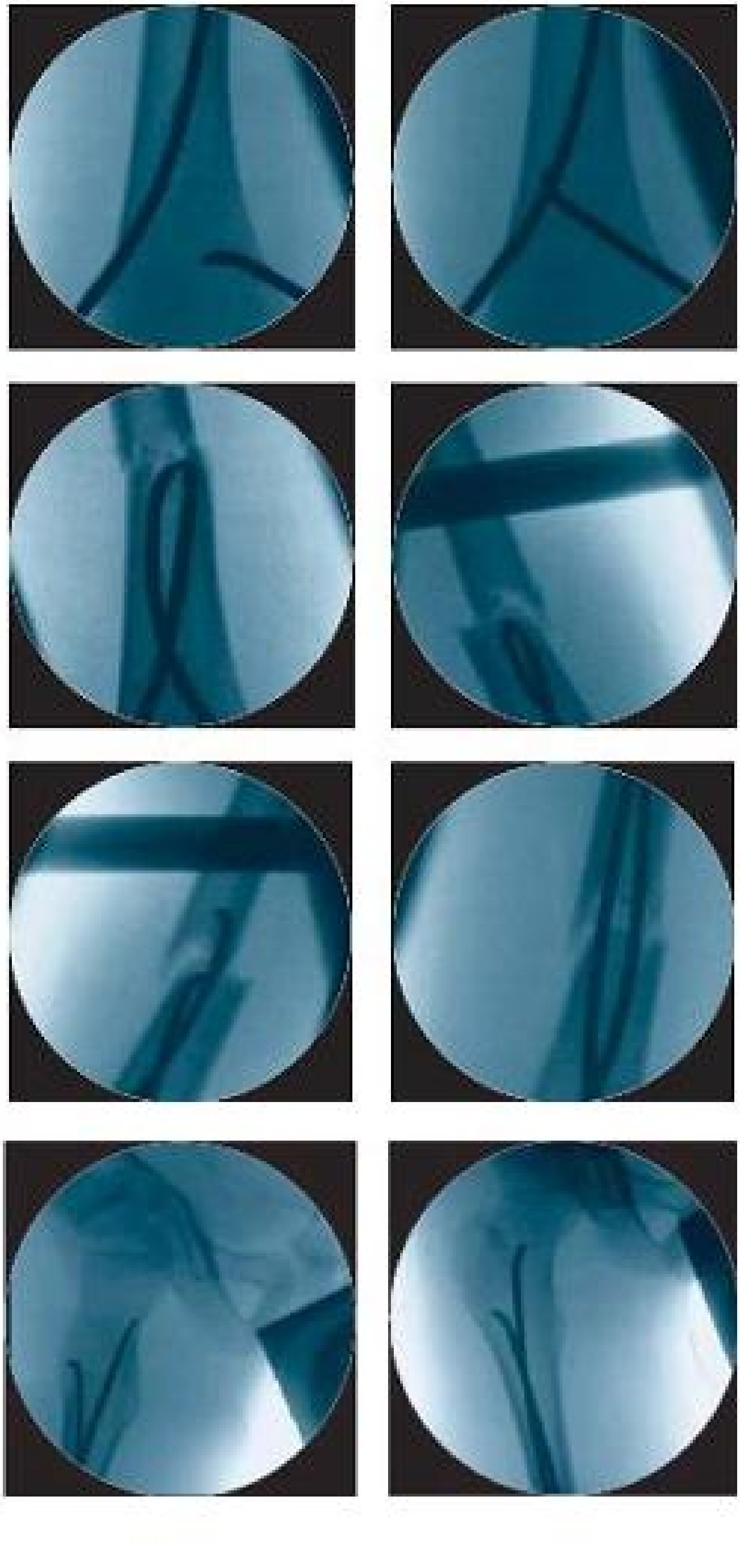


## SURGICAL TECHNIQUE

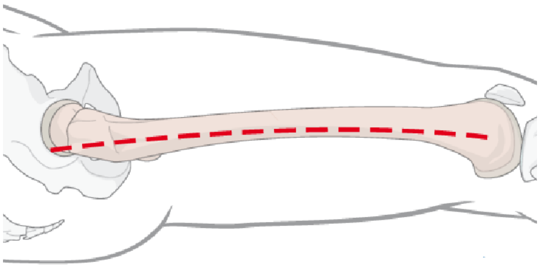


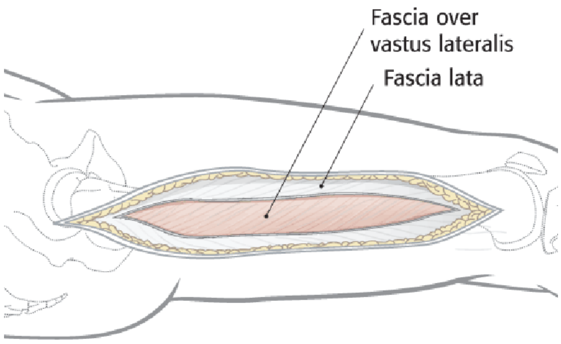


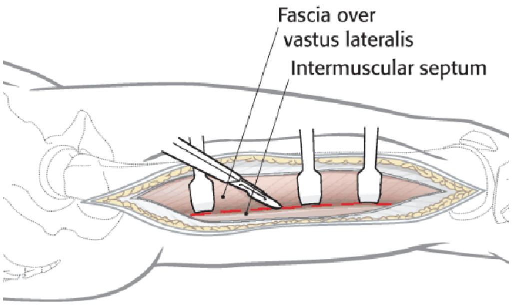
## PASSAGE OF THE NAIL

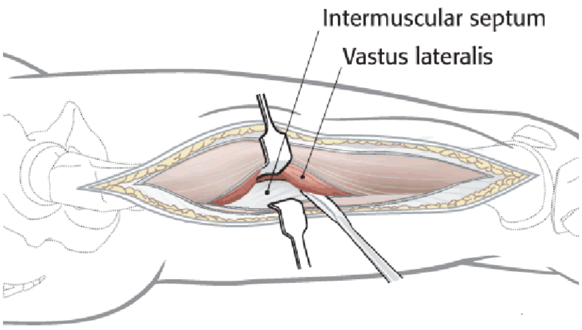


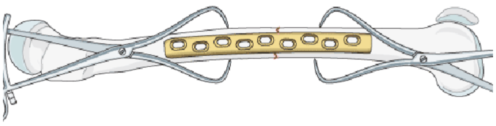
## DYNAMIC COMPRESSION PLATING- STEPS

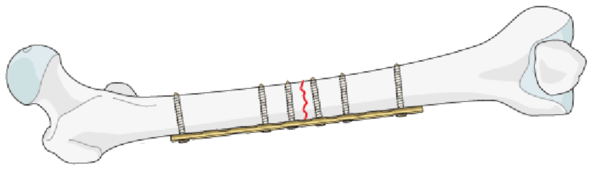




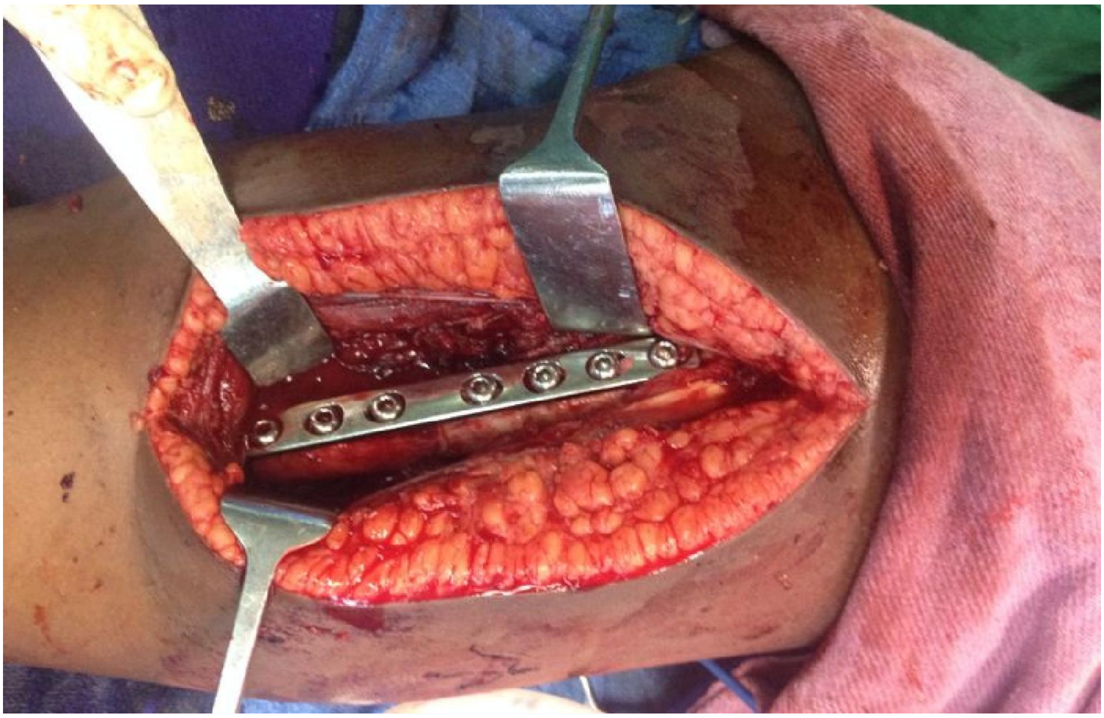





## INTRA OP PICTURE OF FEMUR PLATING



# RESULTS

In our study femoral shaft fractures were found to have high incidence in the age group of 9-10 years. Out of the 20 cases there were 12 (60%) males and 8 (40%) females. The most common mode of injury in our study was fall from height. In this study, 45% had femur shaft fracture in the middle $3^{rd}$.

There were 80% transverse and 20% oblique fractures. The average amount of blood loss in plating was 150 ml and in TENS was 50 ml. Only one patient in plating group was immobilized with above knee slab. Three patients in TENS group were immobilized with above knee slab. Plating group had a mean hospital stay of 18 days. The mean duration for toe touch walking was (started after the appearance of callus radiologically) 10 weeks and the mean duration for full weight bearing was 13.8 weeks in Plating group. In TENS group, the mean hospital stay was 11 days, the mean duration for toe touch walking was 7.42 weeks and the mean duration of full weight bearing was 9.28 weeks.

Table II Comparison of outcome variables between two groups: Significant Limb length inequality ($\geq$2cm) was found in one case

(10%) in the plating group and two cases (20%) in TENS group at the end of 6 months. In all other cases in our study it was <1cm. Malalignment was not observed in the plating group and was noted in two cases (20%) of the TENS group. In the TENS group malalignment was in coronal plane and was <20° in all the cases.

There were two (20%) cases in the Plating group with complications in the form of infection and none of the cases had implant failure. One (10%) patient in the TENS group developed complication in the form of entry point bursitis. Functional outcome was assessed by using Flynn's TENS outcome score, applied to both the groups at the end of follow up. Functional outcome at the end of one year in the Plating group had poor results in three cases (30%) and excellent results in 7 cases (70%). TENS group had poor results in one case(10%), satisfactory results were observed in two cases (20%) and excellent results in 7(70%) cases.

**TABLE II**

| Complications | DCP | TENS | Total |
|---|---|---|---|
| Nil | 7(70%) | 7(70%) | 14(70%) |
| Yes | 3(30%) | 1(10%) | 4(20%) |
| Entry point bursitis | 0 | 1(10%) | |
| Implant failure/knee stiffness | 3(30%) | 1(10%) | 4(20%) |

# DISCUSSION

As surgeons consider different methods to treat paediatric femur fractures and mobilize the injured child, the ideal mode of treatment remains controversial. Titanium elastic nails are popular for the management of length-stable femoral fractures in school going children. Though plating is a treatment option for femoral fractures for the ease of application and early mobilization, recently sub muscular plating has been found to be a successful alternative for the management of length-unstable femoral fractures in school-going children.

In the present study, the average time taken for clinical union in patients treated with DCP was 13.87 $\pm$ 1.8 weeks and in patients treated with TENS was 9.28 $\pm$ 1.49 weeks which was statistically significant ($P<0.01$).

In DCP group the radiological union time (10 $\pm$1.85 weeks) is slightly higher when compared to the results reported with the TENS group (7.42 $\pm$ 0.97 weeks) . In our study, we advised the patients to start toe touch weight bearing with assistive devices as soon as the callus was visible radiologically. DCP group patients started toe touch walking at around 10 weeks, where as TENS group patients started toe touch walking earlier at 8 weeks. These results are similar to Fyodorov et al (6 weeks)[47] and Agus H (8.5 weeks)[48] in those treated with DCP for femur shaft fractures. And the study involving TENS as a treatment modality reports of about 4 weeks (Flynn JM et al). In TENS group only 3(30%) patients were immobilized with above knee slab. Eren OT [49] et al reported about 25% incidence of immobilization in patients treated with DCP and Flynn JM et al reported around 29.3% incidence of immobilization in femur shaft fractures treated with TENS. Similarly, Moroz LA et al[50] report it to be around 22.2% in the TENS Nail. As the decision to immobilize was based on fracture anatomy, the strength of the fixation and confidence of the operating surgeon, it is difficult to draw a statistically valid conclusion.

Intra operative radiation exposure to surgeon is high in closed reduction and TENS group. Kraus et al[51](2008) performed retrospective analysis of 63 femoral and 24 tibial shaft fractures and found that the average radiation time in femoral fractures was 70.3 (range, 12-193) seconds. Standard compression plating is an open procedure. It can be done without the use of intraoperative fluoroscopy.

In our study, after the procedure, all the patients except the ones who were immobilized were advised to move the hip and knee while lying on the bed from the second day. The presence of a large surgical wound and the associated pain in patients treated with DCP may have caused the delay in mobilization. Carey TP et al[52] reported an average time of 5.5 days for mobilization with TENS. Similarly Flynn JM et al reported it as 9 days. Timothy W et al[53] reported an average time for mobilization as six weeks in patients treated with DCP.

In our study, a mean duration of hospital stay in the DCP Group was 18 days and in the TENS Group, it was only 11 days. Many reports suggested that decreased hospital stay in patients treated with TENS compared to those treated with DCP may probably be because of the extensive surgical exposure in DCP group and wound dressings. It was more commonly influenced by the financial constrains of the patient.

In our study we noted that the limb length discrepancy (LLD) was around 1 case (10%) in the DCP group and around 2 cases (20%) in the TENS group. There is a wide range of limb length inequality reported in other studies. Timothy W et al reports 4.3%

whereas, Eren OT et al reporst around 5.4% in femur shaft fractures treated with DCP. In patients treated with TENS, reports by Ligier JN et al, Saikia KC et al and Roop Singh et al [54]have recorded 12%, 13.6% and 8.5% of LLD respectively. Malalignment (angulation or rotation) was not found in the DCP group and was 20% (2) in the TENS Group (varus angulation only, no rotation). None of the cases showed >20° of malalignment. Carey TP et al, Ligier JN et al, Saikia KC et al and Roop Singh et al reported 8%, 11%, 9.09% and 8.57% incidence of malalignment in cases treated with TENS respectively.

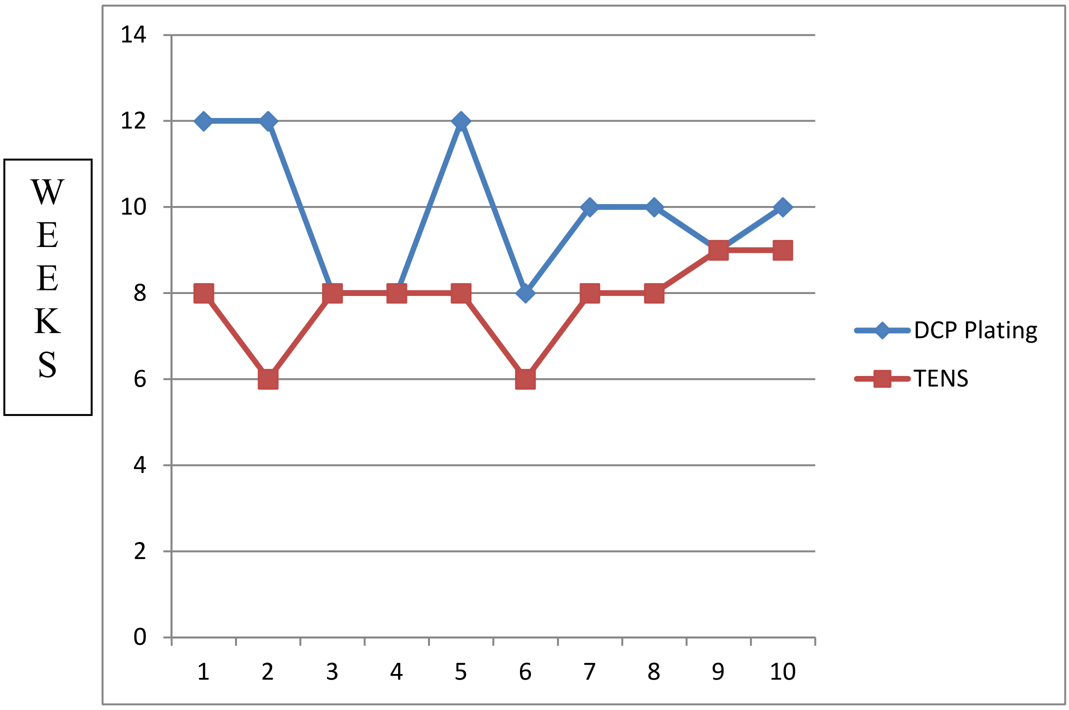
In our study, 2 cases out of 8 in DCP group developed complications in the form of infection and wound debridement was done and one case (10%) developed knee stiffness. The patients (2) who had infection were dealt individually. In TENS group one patient(10%) developed knee stiffness. Two patient (20%) developed nail irritation and pain which mandated the removal at the 4$^{th}$ month post operatively.

Functional outcome was assessed in both DCP and TENS group by applying the Flynn's outcome scoring system (2004) at the end of one year. DCP group had poor results in 3 cases (30%) and excellent results in 7 cases (70%). In the TENS group, Poor results in one case(10%), satisfactory results were observed in 2 cases (20%) and excellent results in 7 cases (70%).

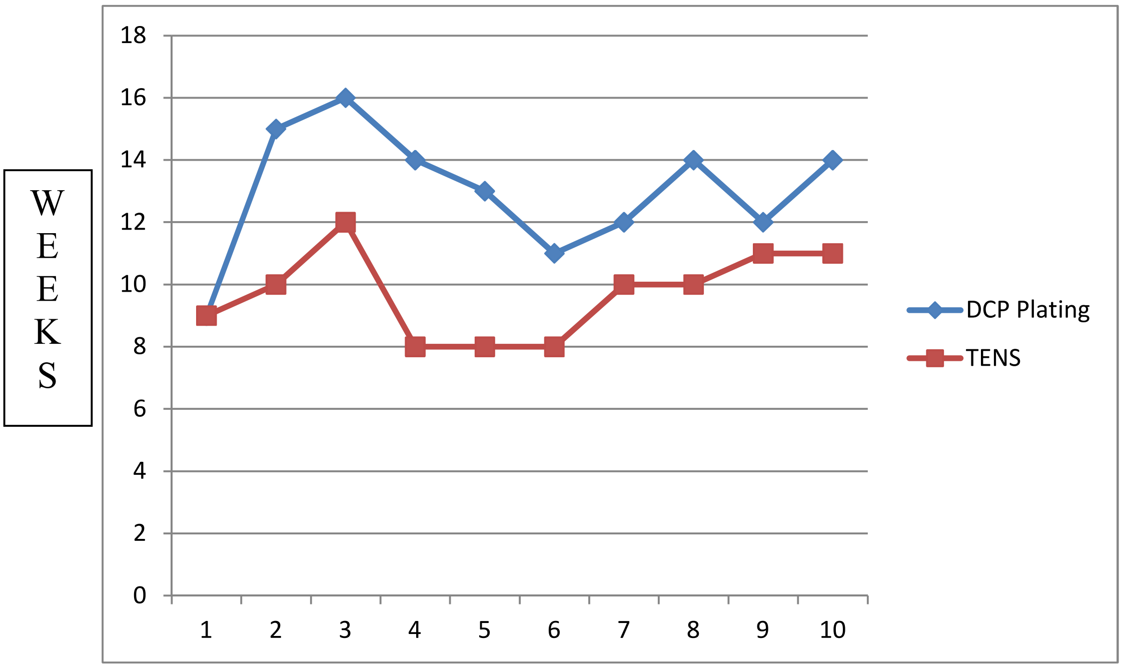
# STATISTICAL ANALYSIS

Plating group has a mean radiological union of 9.9 $\pm$ 1.66 weeks. TENS group has a mean radiological union of 7.80 $\pm$ 1.03 weeks, which is statistically significant ($p < 0.01$). Plating group has a mean clinical union (full weight bearing) in 13 $\pm$ 2.05 weeks. Comparatively, the TENS group has a mean clinical union in 9.7 $\pm$ 1.4 weeks, which is statistically significant ($P<0.01$)

**Radiological union**



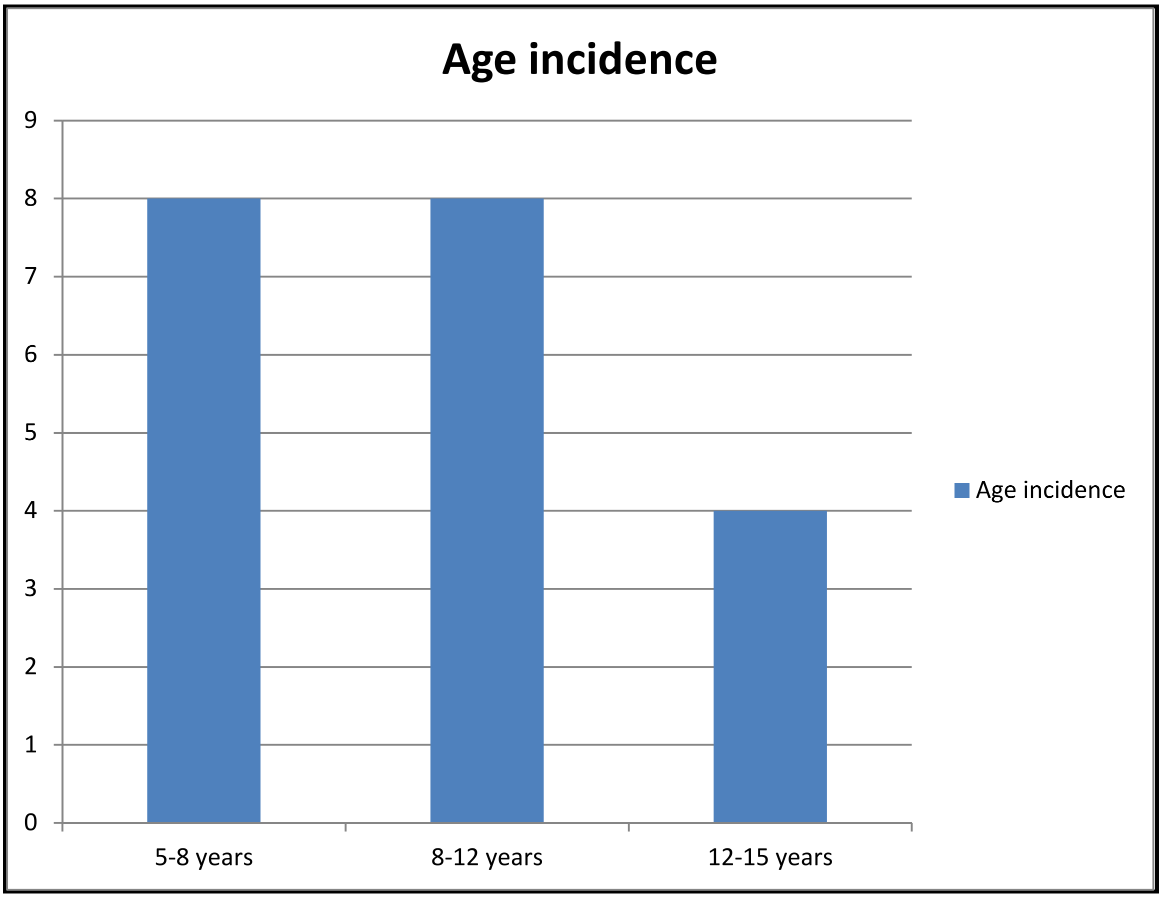

**Clinical union (full weight bearing)**

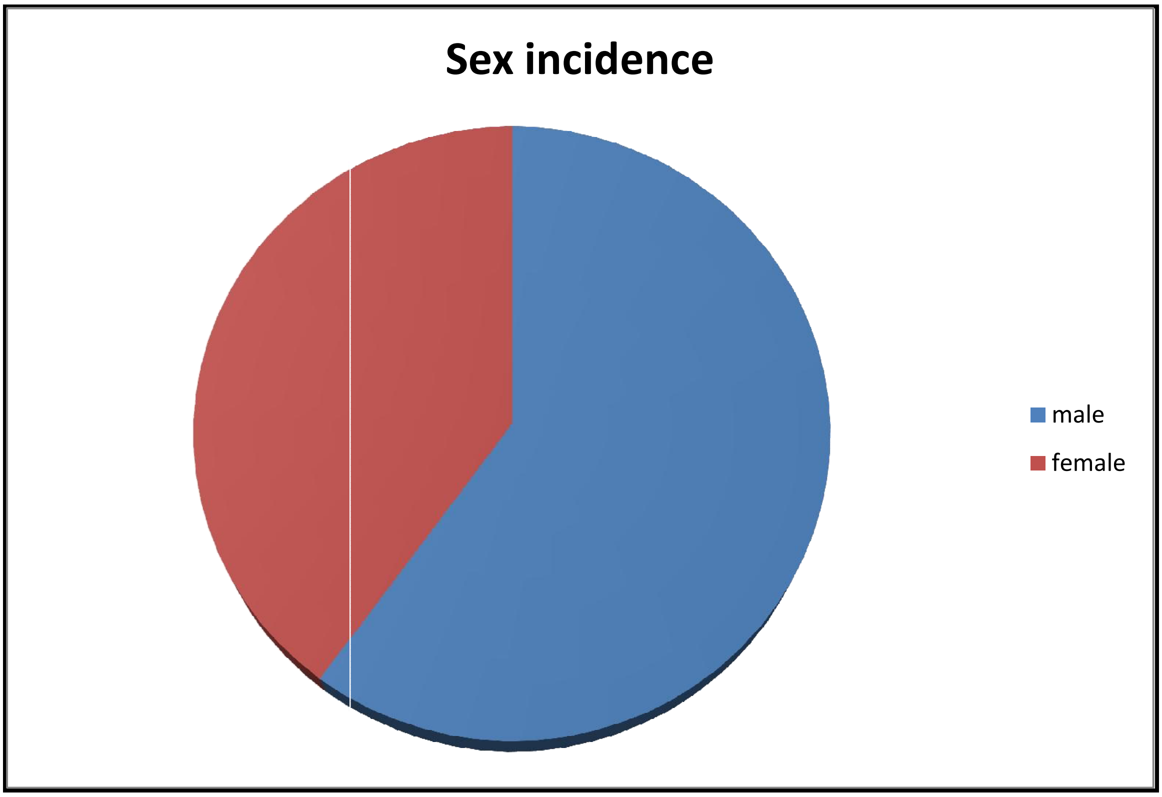


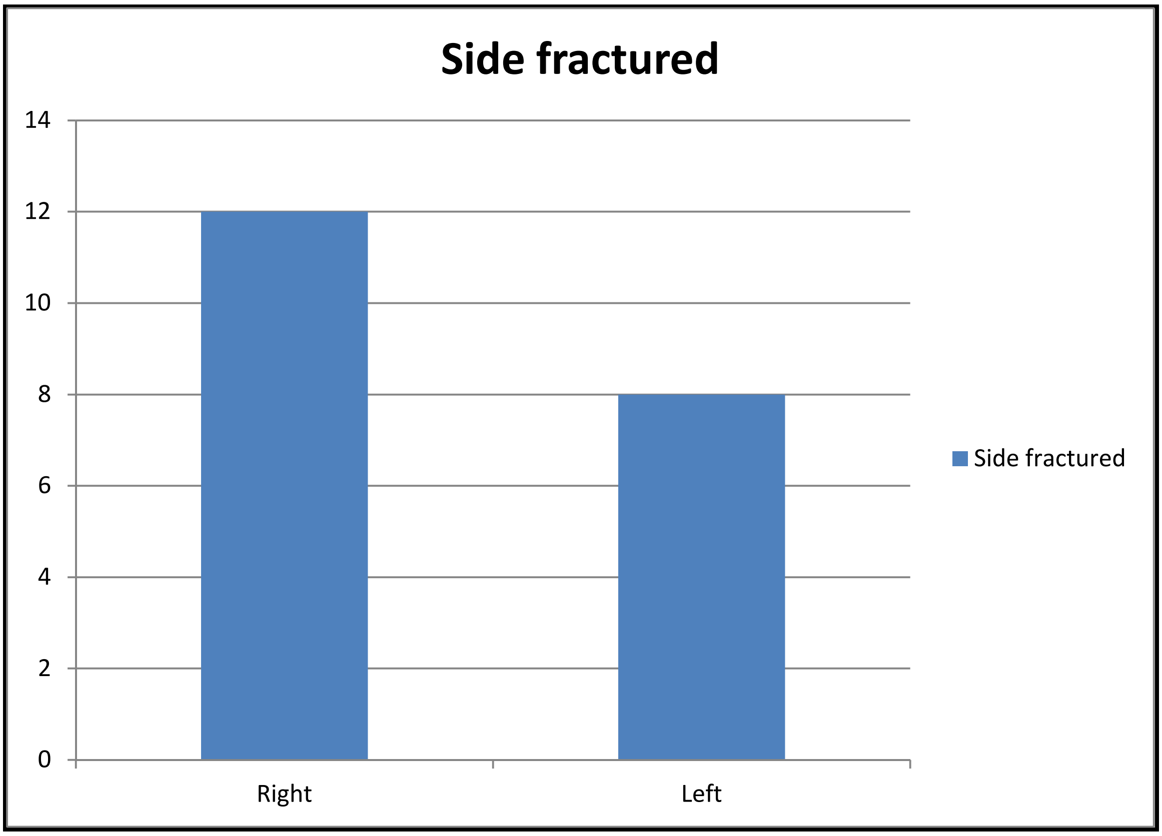
# CONCLUSION

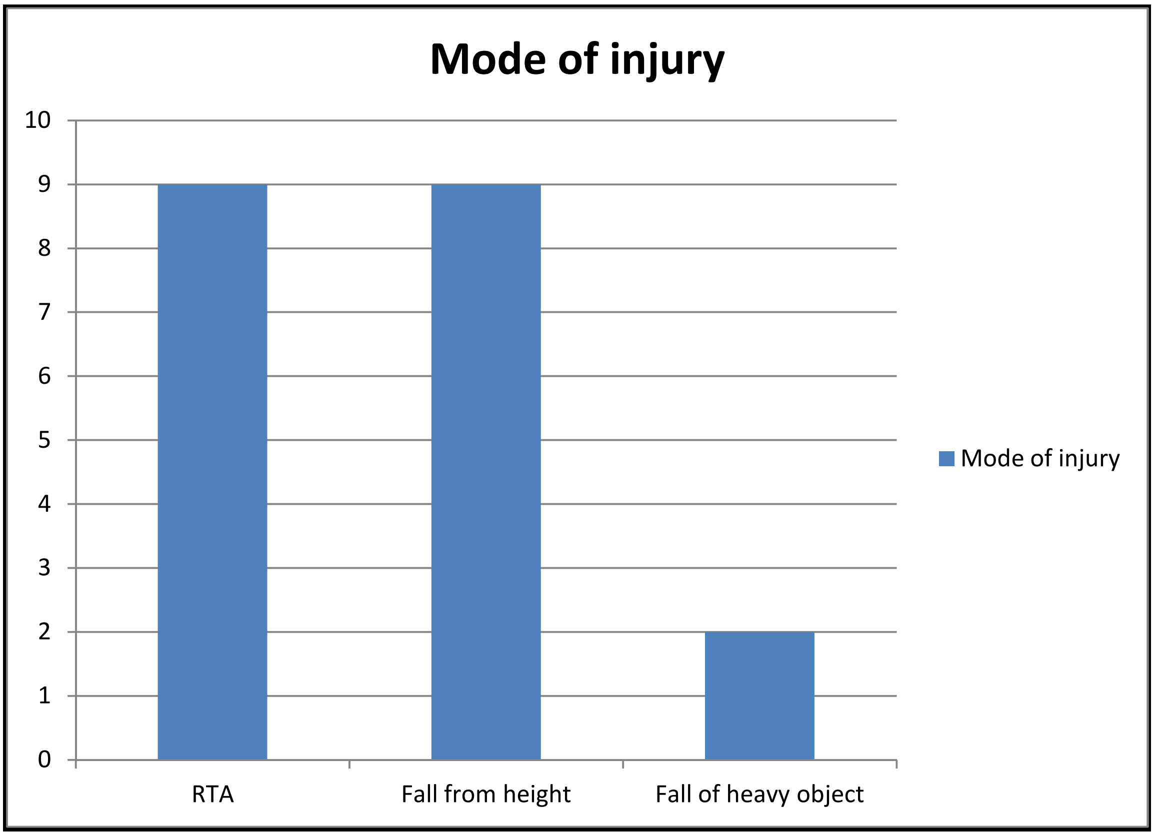
In our study, the TENS patients have minimal blood loss, the procedure is minimally invasive and has a good early union rate, short hospital stay & early return to school for the children. TENS has less infection rates when compared to Dynamic Compression Plating and is easy to remove.

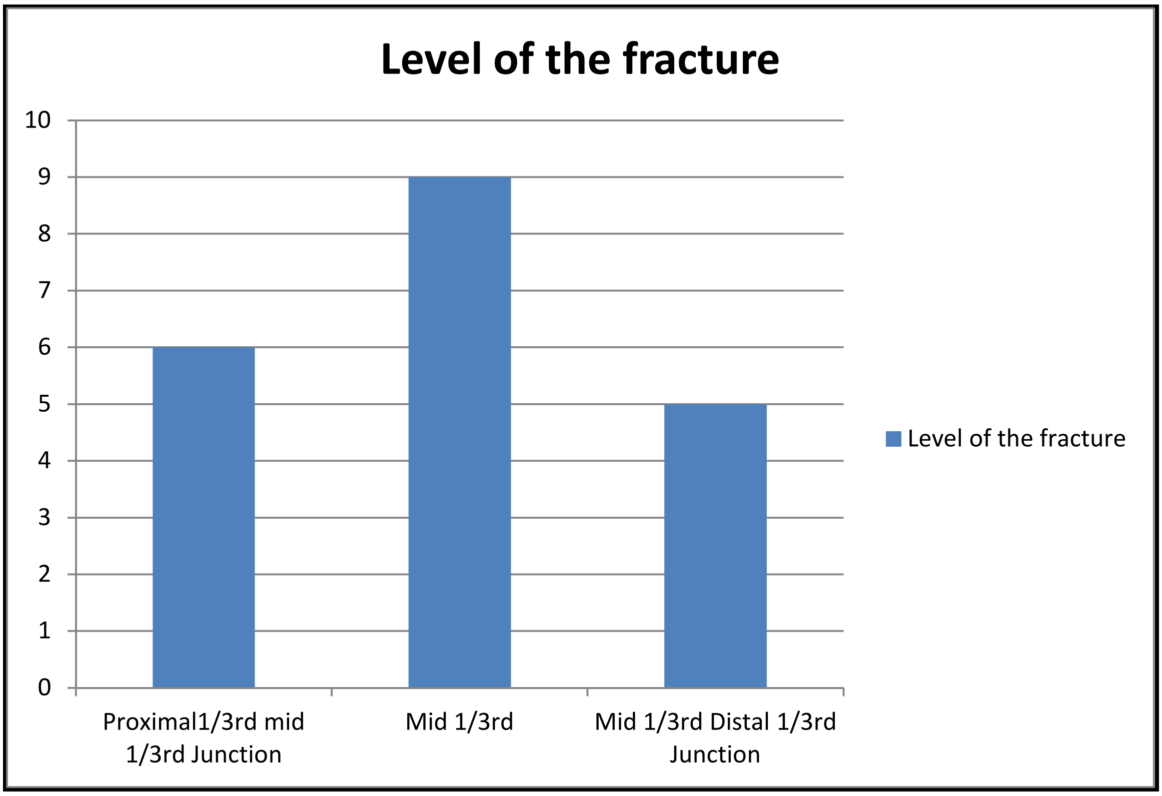
The only disadvantage is radiation and some cases required short term immobilization to avoid angulation/ malalignment. There is no growth plate damage reported in our study. Even though the functional outcome at the end of one year are statistically similar, TENS has many significant advantages over plating in terms of patient morbidity. We conclude that TENS is the implant of choice for femoral diaphyseal fractures in children aged from 6-14 years.

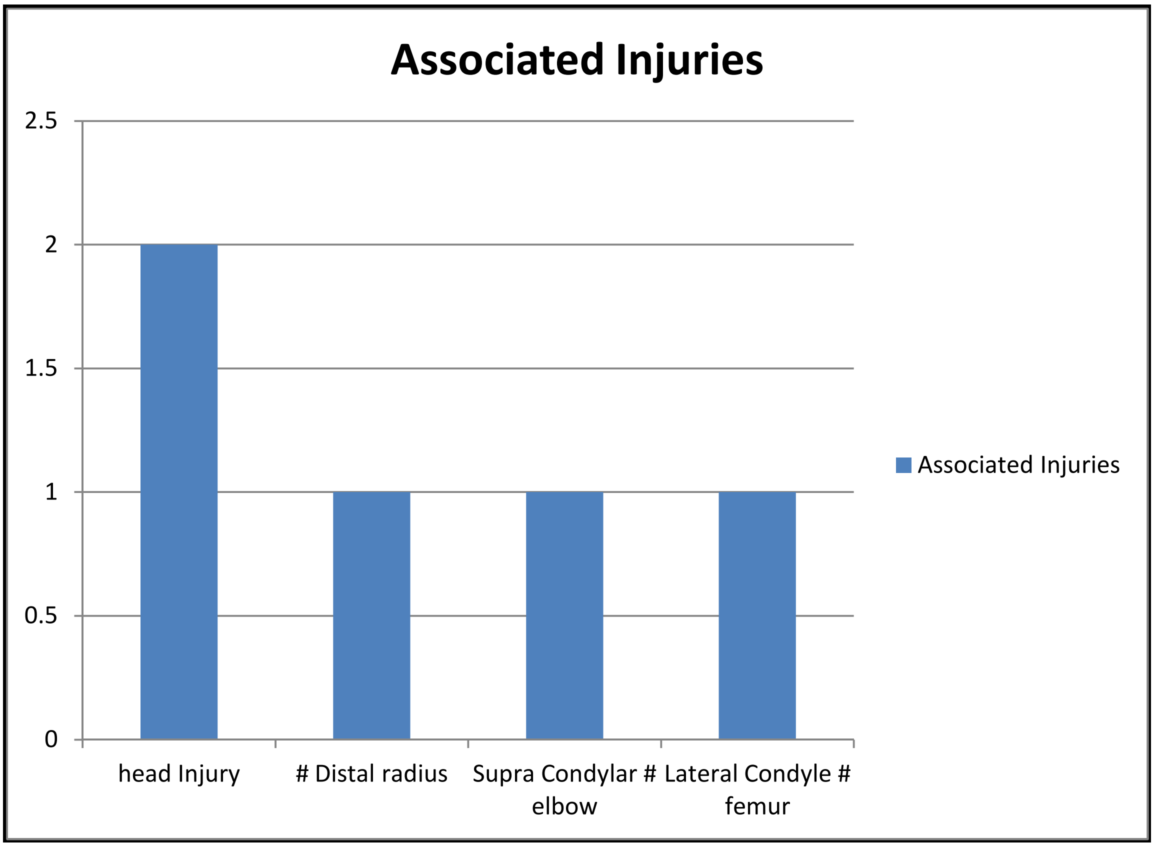

Age incidence
9
8
7
6
5
4
3
2
1
0
5-8 years
8-12 years
12-15 years
Age incidence

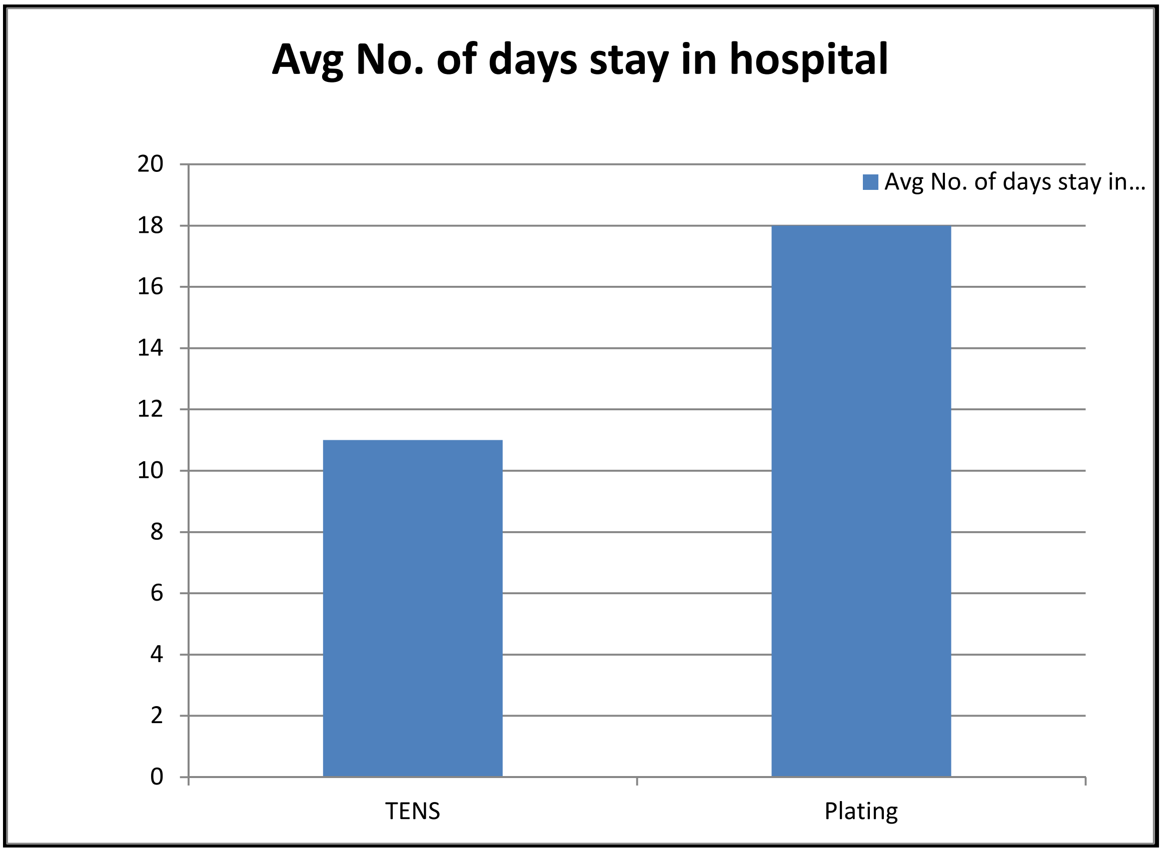

Sex incidence
male
female

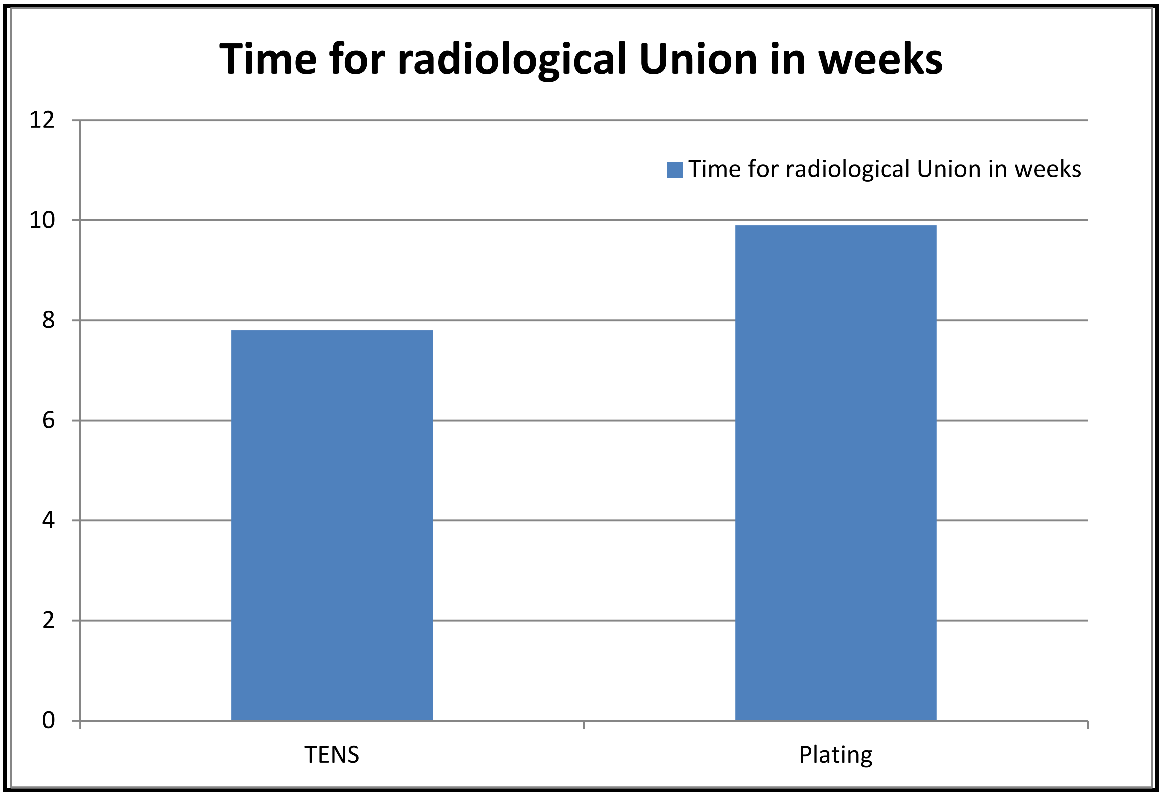

Side fractured
14
12
10
8
6
4
2
0
Right
Left
Side fractured

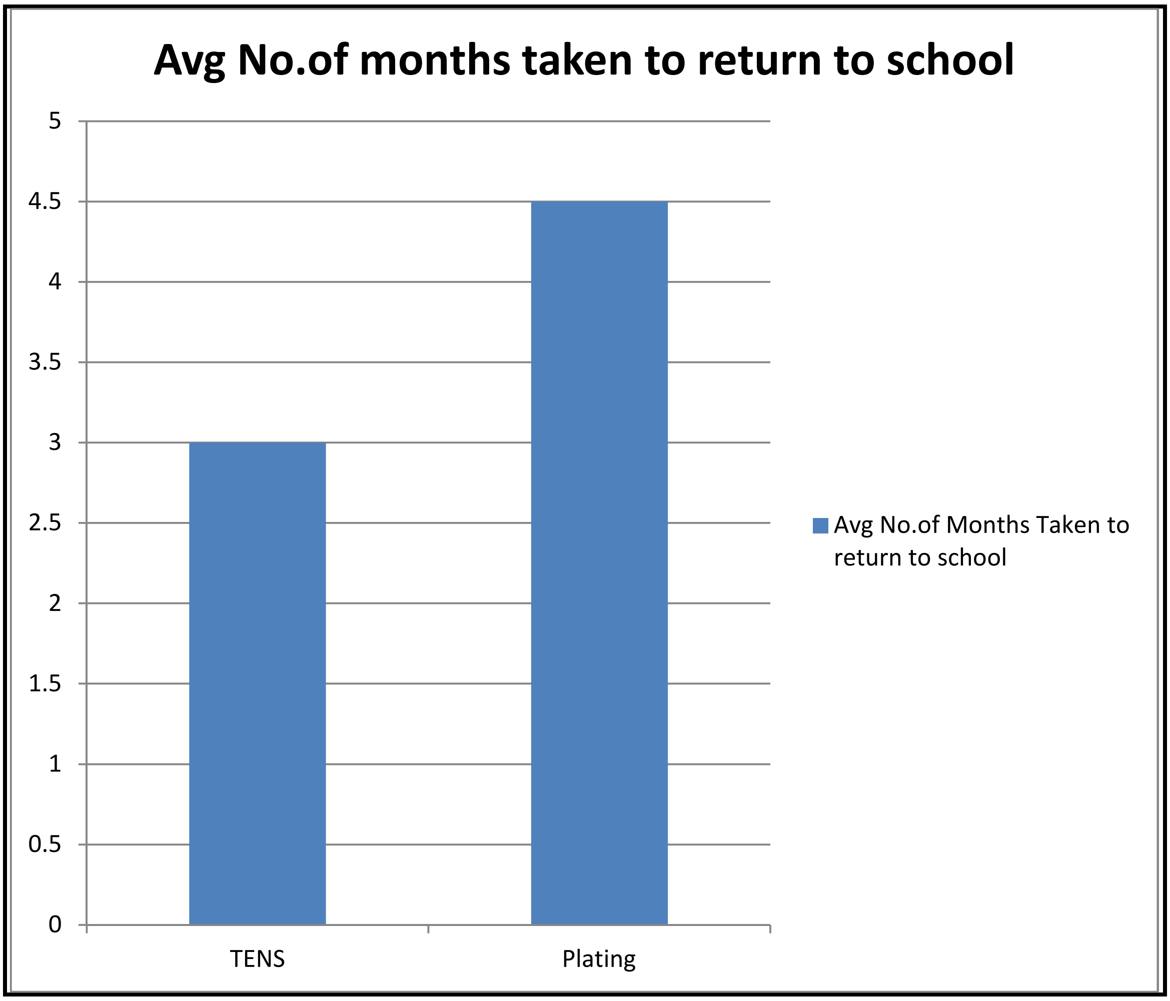

Mode of injury
10
9
8
7
6
5
4
3
2
1
0
RTA
Fall from height
Fall of heavy object
Mode of injury

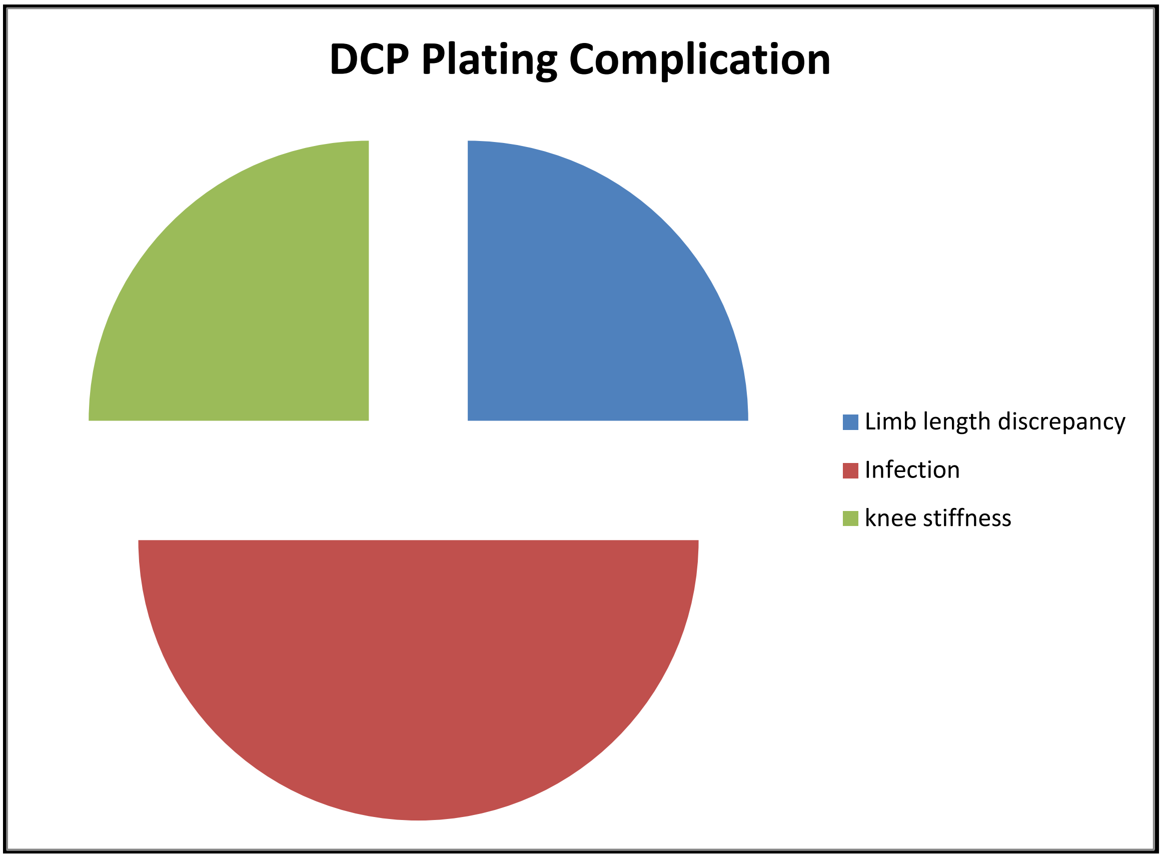

Level of the fracture
10
9
8
7
6
5
4
3
2
1
0
Proximal1/3rd mid 1/3rd Junction
Mid 1/3rd
Mid 1/3rd Distal 1/3rd Junction
Level of the fracture

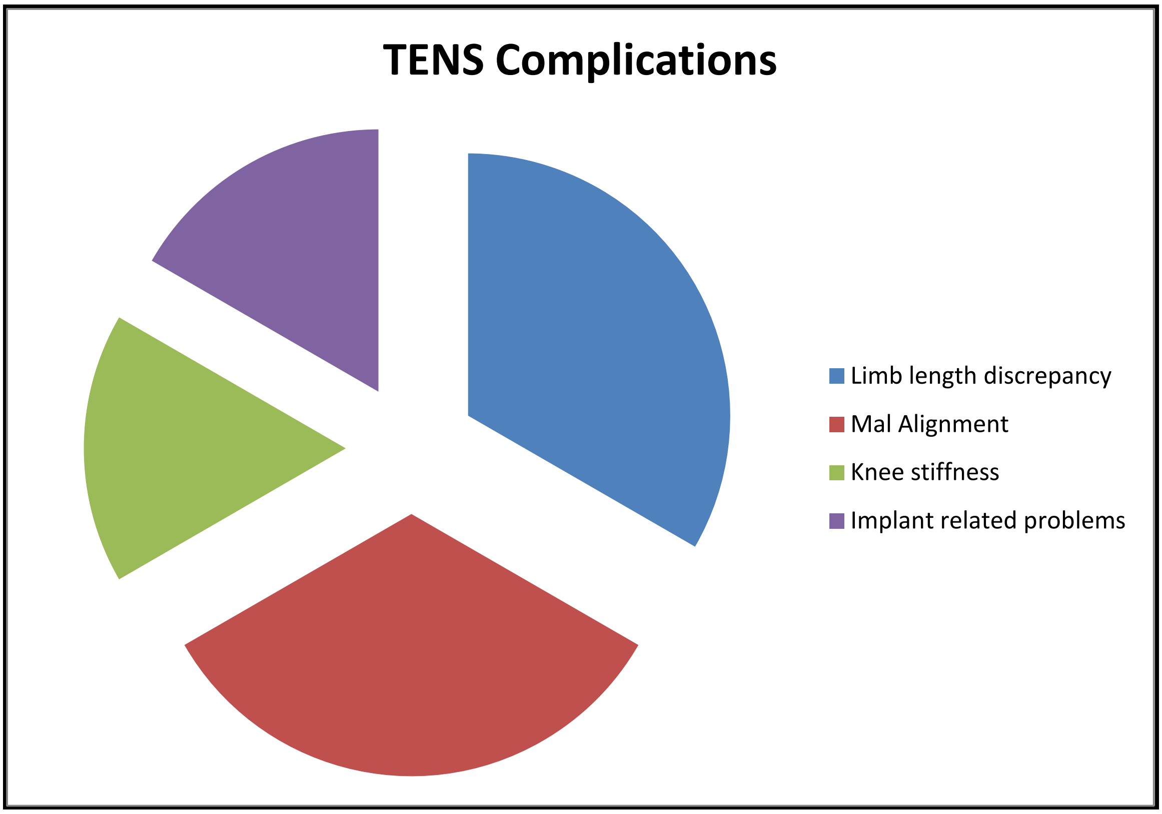

Associated Injuries
2.5
2
1.5
1
0.5
0
head Injury
# Distal radius
Supra Condylar # elbow
Lateral Condyle # femur
Associated Injuries


Avg No. of days stay in hospital
20
18
16
14
12
10
8
6
4
2
0
Avg No. of days stay in...
TENS
Plating


Time for radiological Union in weeks
12
10
8
6
4
2
0
Time for radiological Union in weeks
TENS
Plating


Avg No.of months taken to return to school
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
TENS
Plating
Avg No.of Months Taken to return to school


DCP Plating Complication
Limb length discrepancy
Infection
knee stiffness


TENS Complications
Limb length discrepancy
Mal Alignment
Knee stiffness
Implant related problems

# MASTER CHART

| S No | Patient name | Age | Sex | IP No | Type of fracture | LLD upto 2cm | Angulation >10$^{o}$ | Clinical abnormality | Radiological union In weeks | Clinical Union In weeks | Results |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lokesh | 8 | Male | 85270 | Transverse | nil | nil | - | 12 wks | 16 wks | Excellent |
| 2 | Sangeetha | 14 | Female | 4178 | Transverse | nil | nil | - | 12 wks | 15 wks | Excellent |
| 3 | Madhubalan | 12 | Male | 40666 | Transverse | nil | nil | Knee stiffness | 8 wks | 16 wks | Poor |
| 4 | Jhonson | 5 | Male | 72688 | Transverse | nil | nil | - | 8 wks | 14 wks | Excellent |
| 5 | Lokesh | 8 | Male | 55423 | Transverse | nil | nil | Infected | 12 wks | 13 wks | Poor |
| 6 | Manojkumar | 7 | Male | 130640 | Oblique | nil | nil | - | 8 wks | 11 wks | Excellent |
| 7 | Vetriselvan | 6 | Male | 15119 | Transverse | nil | nil | - | 10 wks | 12 wks | Excellent |
| 8 | Narmatha | 9 | Female | 33360 | Oblique | yes | nil | Infected | 10 wks | 14 wks | Poor |
| 9 | Jeevitha | 8 | Female | 93917 | Transverse | nil | nil | - | 8 wks | 10 wks | Excellent |
| 10 | Bharath | 8 | Male | 8472 | Transverse | nil | nil | - | 9 wks | 11 wks | Excellent |

| S No | Patient name | Age | Sex | IP No | Type of fracture | LLD upto 2cm | Angulation >10$^{o}$ | Clinical abnormality | Radiological union In weeks | Clinical Union In weeks | Results |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | Madhavan | 12 | Male | 50016 | Transverse | nil | nil | - | 8 wks | 9 wks | Excellent |
| 12 | Priyadharshini | 11 | Female | 32932 | Oblique | nil | yes | Local irritation | 6 wks | 10 wks | Successful |
| 13 | Indhumathy | 8 | Male | 132786 | Transverse | yes | nil | B/L knee stiffness | 8 wks | 12 wks | Poor |
| 14 | Narmatha | 9 | Female | 33360 | Transverse | nil | nil | - | 8 wks | 8 wks | Excellent |
| 15 | Vinoth | 13 | Male | 45964 | Transverse | nil | yes | - | 8 wks | 8 wks | Excellent |
| 16 | Priyadharshini | 9 | Female | 57253 | Transverse | yes | nil | - | 6 wks | 8 wks | Excellent |
| 17 | Albert | 6 | Male | 51658 | Transverse | nil | nil | | 8 wks | 10 wks | Excellent |
| 18 | Kathiresan | 9 | Male | 61456 | Transverse | nil | nil | Local irritation | 7 wks | 9 wks | Successful |
| 19 | Vimalraj | 8 | Male | 34565 | Transverse | nil | nil | - | 7 wks | 9 wks | Excellent |
| 20 | Sasikumar | 8 | Female | 87773 | Oblique | nil | nil | - | 8 wks | 10 wks | Excellent |

# CASE 1 – TENS NAIL

## MADHAVAN 12/MALE

***Pre OP***

***Post OP***

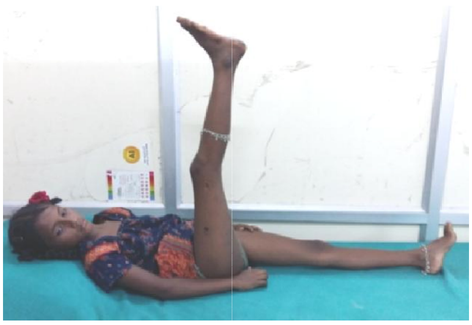

***2 Years Post OP***

# CASE 2 – TENS NAIL

**PRIYADHARSHINI 9/FEMALE**

***Post OP***


***6 months follow up***



# CASE 3 – TENS NAIL

## PRIYADHARSHINI 11/FEMALE

Post OP



6 Months follow up

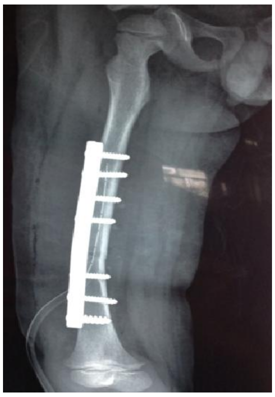
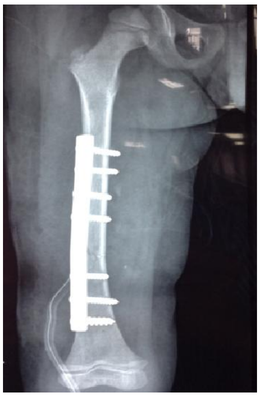
# CASE 4 – PLATING

## JHONSON 6 YEAR /MALE

***Pre OP***



***Post OP***

***1 year Post OP***

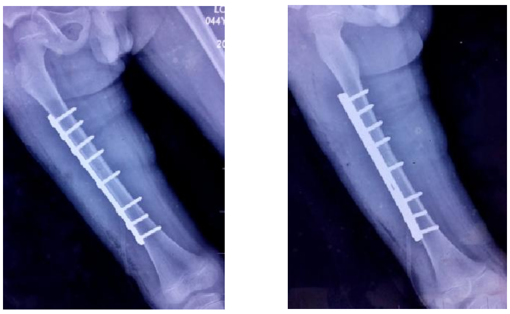

***1 year follow UP***


# CASE 5 – PLATING

## LOKESH 8 YEAR/ MALE

***Pre OP***

***Post OP*** ***1 Year Post Op***




***1 year follow Up***

# CASE 6 – PLATING

## MADHUBALAN 13/MALE

***Pre OP***

***Post OP***



***1 Year follow Up***

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# PROFORMA

Serial No. I.P. No:

Name : DOA:

Age : DOS:

Sex: DOD :

Address :

Hospital :

Occupation: Unit:

Informant :

**HISTORY**

Presenting Complaints :

a) Pain in the thigh
   - o Onset
   - o Duration
   - o Type and Severity
   - o Aggravating / Relieving factors

b) Swelling

c) Restriction of movements

d) Deformity

History of Presenting Illness

- Mode of injury
- Place of injury Domestic / Road traffic accident / Farm Yard / Assault/ others

Associated injuries if any:

Past History

H/O DM/ HTN / TB / IHD / Bronchial Asthma

Family History

H/O DM / HTN / TB in the family

Personal History

- Socio-economic status
- Diet
- Appetite
- Sleep
- Micturition / Bowel

**EXAMINATION**

General Examination

- Built
- Vitals

| | |
|---|---|
| Pulse: | BP: |
| RR: | Temperature : |

- Pallor / Icterus / Cyanosis / Clubbing / Edema / Lymphadenopathy

Systemic Examination

| | |
|---|---|
| CVS - | RS - |
| P/A - | CNS - |

Local Examination of Thigh:

- Gait
- Attitude

Inspection

- Swelling
- Deformity
- Wounds if any

Palpation:

- Local rise of temperature
- Local tenderness
- Swelling
- Crepitus
- Abnormal mobility
- Bony irregularity
- Distal pulsation

Range of Movement :

- Hip joint movements
- Knee joint movements

Measurements: Right/ Left

- Length of the thigh segment

Neurological Examination

## INVESTIGATIONS

**Routine:**

- Blood

    Hb%: TC: DC: ESR:

- Urine : Albumin : Sugar : Microscopy :
- RBS
- Blood Urea
- Serum Creatinine
- HIV
- HBsAg

**X-ray**

- Plain X-ray of full length of femur including hip and knee joint
    - AP
    - Lateral View
- Report
- Side affected Right / Left
- Side of fracture : Proximal $1/3^{rd}$

    Middle $1/3^{rd}$

    Distal $1/3^{rd}$

Type of fracture : Transverse / Oblique / Spiral / Segmental / Comminuted

**SPECIAL INVESTIGATIONS**

**DIAGNOSIS :**

**MANAGEMENT**

- Immobilization

Surgical Management

  - DOS – date of Surgery
  - Duration between trauma and surgery
  - Pre operative antibiotics
  - Anaesthesia – general or spinal
  - Procedure
  - Duration of surgery

**OPERATIVE FINDINGS**

**TENS Nail:**

Closed/Open

Size of Nail :

  - Medial
  - Lateral

Difficulties during operation

  - Difficulty to active reduction
  - Difficulty in passing nail
  - Others

**Dynamic Compression Plating:**

Broad DCP/Narrow DCP used

Any Lag screws :

Blood Loss :

Difficulties during operation

Management of other fractures and injuries

## POST OPERATIVE MANAGEMENT

- Antibiotics
- Post operative X-ray
- Post operative immobilization
- Wound care
- Quadriceps set exercise
- Knee bending exercise
- Non weight bearing crutch walking / walker
- Date of suture removal

## ADVICE AT THE TIME OF DISCHARGE

- Quadriceps exercise
- Active movements of the hip and knee

## FOLLOW UP

-

| Complications | 6 weeks | 12 weeks | 24 weeks | 1 year |
|---|---|---|---|---|
| Pain / deformity/swelling/ difficulty in walking / discharging wound others | | | | |
| On Examination<br>Tenderness<br>Shortening / Lengthening<br>Knee Movement<br>Muscular atrophy<br>Rotational alignment of the lower limb | | | | |
| X-ray<br>Callus formation / union<br>Varus / Valgus alignment<br>AP angulation | | | | |
| Distal migration of the nail<br>Restriction of knee flexion<br>Infection<br>Delayed union / non union | | | | |
| Advice<br>Quadriceps exercise<br>Weight bearing | | | | |
| Others | | | | |